Giovanni Gianni Becattini

Tektronix oscilloscopes

A photo report about Tektronix 7000-Series oscilloscopes

E03

Foreground

Tektronix (shortly "Tek") is today a large company, founded in 1945, building electronic instruments. For most of my generation, Tektronix "is" the oscilloscope itself. Many others came after Tek in the oscilloscope market, and Tek's activity has not been limited to oscilloscopes, but, for us, the word "Tektronix" is and will remain the synonym of oscilloscope.

In 1973, the 7603 was for most of us an impossible dream, like a Ferrari or a Jaguar. I remember that, when I was at the university and by my own I started to work on microprocessors, asked my Professor to be allowed to use it. "No", he said, "it's too early". And then added: "...and forget this microprocessor thing. They have no future...". I had to wait another year and a new professor, who became my partner in the first company I founded.

My first "true" oscilloscope, in 1974, was a Tektronix 545. It was very heavy (if I correctly remember, it used near 50 tubes...) and I bought it in Milan, far about 300 km from home. But how to carry it home by train? I asked the help of a friend, and of my girlfriend at that time, Margherita. It was hard, but we succeeded. When we came home, I was attacked by the parents of Margherita, who thought we were escaped for love... (in the seventies the world was different). At the end, I could prove the truth, but that did not produce a better idea of me... "Really for what... an ***oscilloscope****? Sis, said her brother, you'd better find a different boyfriend...". Later, I wrote an article for an Italian magazine (Dec 1974), based on that 545, that I repaired and calibrated. It is shown here on the left and can be still today downloaded from the Internet.*

Returning to today, in my taste, the seventies Tektronix scopes are the most fascinating, and I own today an unreasonable number of them; I will show you the pieces I love more.

Why this book? Simple: I love this kind of equipment. Wonderful classic equipment, that made the history of the technology, and that today we have the pleasure to preserve for the future.

I hope that these pages will be appreciated by others who, like me, like these witnesses of a distant era.

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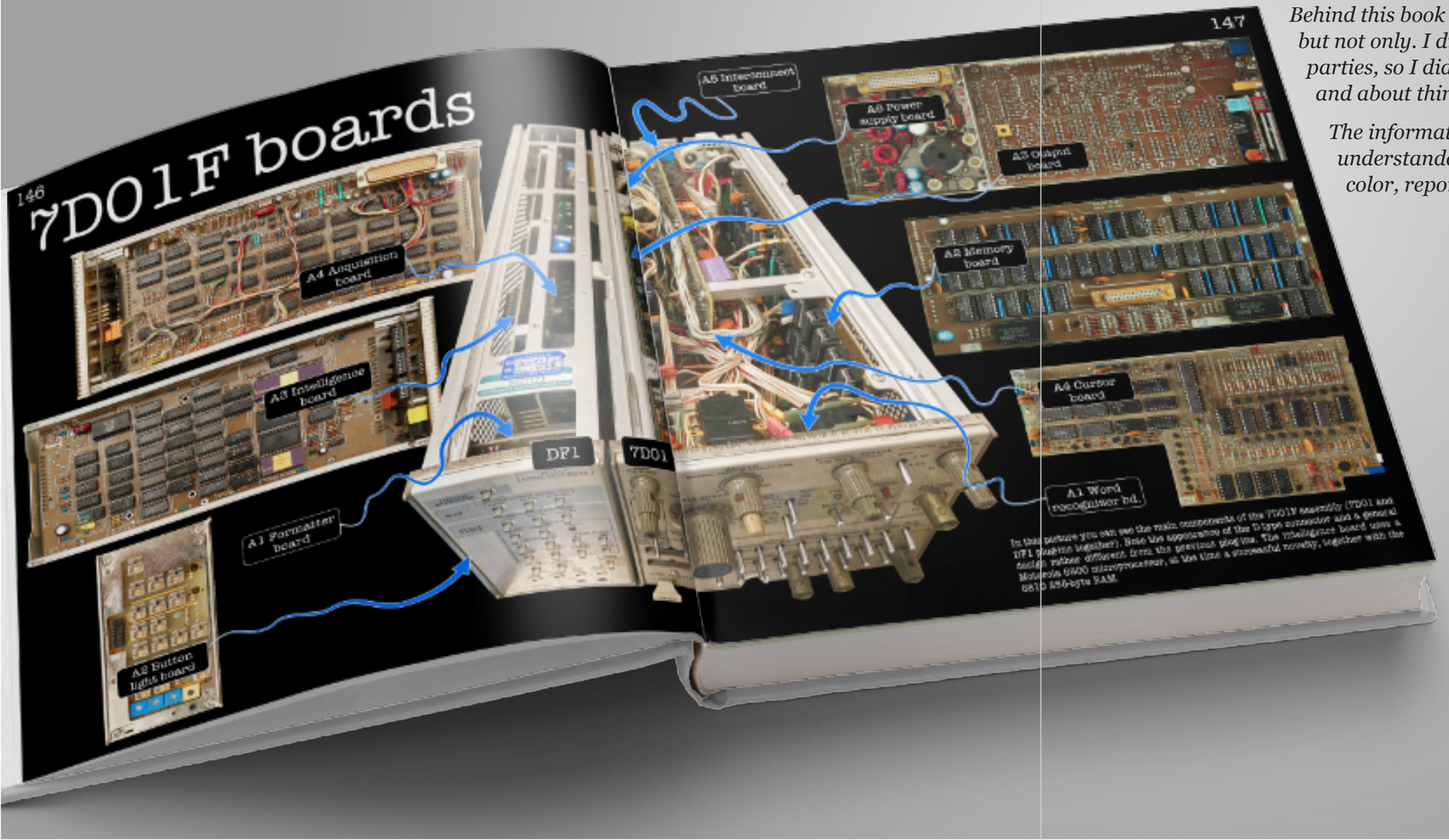
Organization of this book



Behind this book there is a huge work of Internet research and photo editing, but not only. I didn't want just to collect and reproduce material from third-parties, so I did my best to talk only about equipment that I really own, and about things that I could really test.

The information here contained is huge, so, to make the things more understandable, I divided the book in four main sections, identified by a color, reported on the right side of each right page:

7000-Series key points

7000-Series mainframes

7000-Series plug-ins

7000-Series restoration

NOTICE: I don't claim any historical rigor, I am not an expert of this matter. Even though I am an electronics professional, in this case I work as a simple enthusiast, with limited means and a home laboratory. If I wrote something wrong, or infringed somebody else's rights, please write me and I will amend consequently.

COPYRIGHT: I wish to keep the copyright of this book. Besides that, this book is absolutely free, I wrote it just for my amusement. You can copy, print and/or distribute it as you want, and even sell, if you can, provided that you don't modify it.

PLEASE LINK ME: If you like, I will be grate if you link its download page (http://www.k100.biz/parade.htm).

Preface to this E03 edition

The most important addition is the mythical 7854, that, for us crazy collectors, is like owning "La Gioconda" Da Vinci's picture, that one could stay hours just looking at it... Still not a true DSO like we consider it today, but far ahead of the old 7904/P7001 DPO. A real turning point in the evolution of oscilloscopes, with solutions that are still futuristic today, such as the possibility of being programmed with high-level (at least for the time) languages, that add a whole new dimension of amusement for obsessed people like me. The work is not finished, because I am still repairing it, you will get more of it in the future editions.

You will find also some pages dedicated to the wonderful VintageTEK museum and a lot of other additions/corrections, that incremented by 106 the number of pages respect to the previous edition.

I wish to add that the readers of this book are very kind, they sent me their appreciation and omitted to make evident a big mistake that I made. I talked about the CRT-storage 7833 as the best ever, forgetting the 7834 and the 7934. I corrected that, adding two photos of these advanced scopes got from TekWiki, because I don't own them.

E03 *To make easier pointing out the differences with the previous edition, check the pages marked with the green "E03" circle.*

DOWNLOAD ME TOO, I AM FREE!

The "Surplus photo parade" book is related mostly to old military surplus radio equipment and instruments, describing, in 164 pages, tens of devices with a large number of photos. You can download it for free from http://www.k100.biz/parade.htm

What's an oscilloscope?

An oscilloscope is, for the electronic engineer, what the microscope is for the biologist: an instrument that allows to overcome the limitations of our senses, to see something that is too small or too different from us to be investigated.

Basically, an oscilloscope is an instrument capable to see the rush of moving electrons, or, more precisely its effects, i.e. to measure voltage trends in the time domain, in an electric wire.

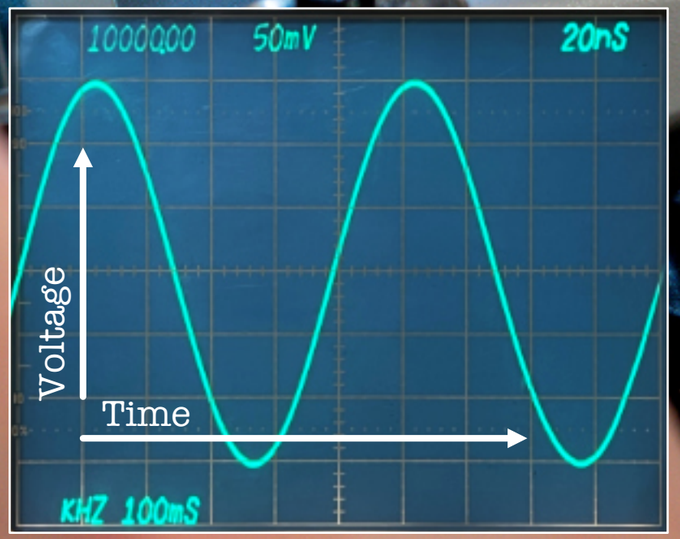
The oscilloscope shows its results thru a graphic display as a two-dimensional plot; in the x-axis you have the time and in the y-axis the voltage value. So, it is possible to analyze the electric signal, to measure its properties (such as amplitude, frequency, rise time, time interval, distortion etc.).

We could do the same thing with a voltmeter and a watch: at time zero you read the value indicated by the voltmeter and write it down on a sheet. After a minute, you read again the voltmeter value and, again, write the new value on the sheet, constructing an x-y plot. After two minutes, again... But if you need to do the measure every two seconds, things become more difficult, and more for shorter times. An oscilloscope like the 7904, allows to trace the trend of the voltage down to ***half a billionth*** *of a second per each division on the screen.*

Before the 7000-Series, subject of this book, those values required manually measuring the waveform against the scales built into the screen of the instrument. The quality of the display (Cathode Ray Tube or CRT) was thus very important, and Tektronix was a leader producing high quality CRTs.

Today, Digital Storage Oscilloscopes (DSO) are capable of analyzing automatically the signals, calculating and displaying the required values. But already with 7000-Series, new plug-ins were gradually introduced, with the purpose of automatic analyzing the signal. For example, the 7D15 plug-in was capable of automatically evaluating and presenting on the CRT precise values such as frequency or period, without the need for the operator to measure the waveform on the screen (a sample here in the right).

Oscilloscopes are used not only by electronic technicians, but in the sciences, medicine, engineering, automotive, telecommunications industry etc., whenever a physical quantity can be converted to an electric signal. For instance, to display the waveform of the heartbeat (electrocardiogram).



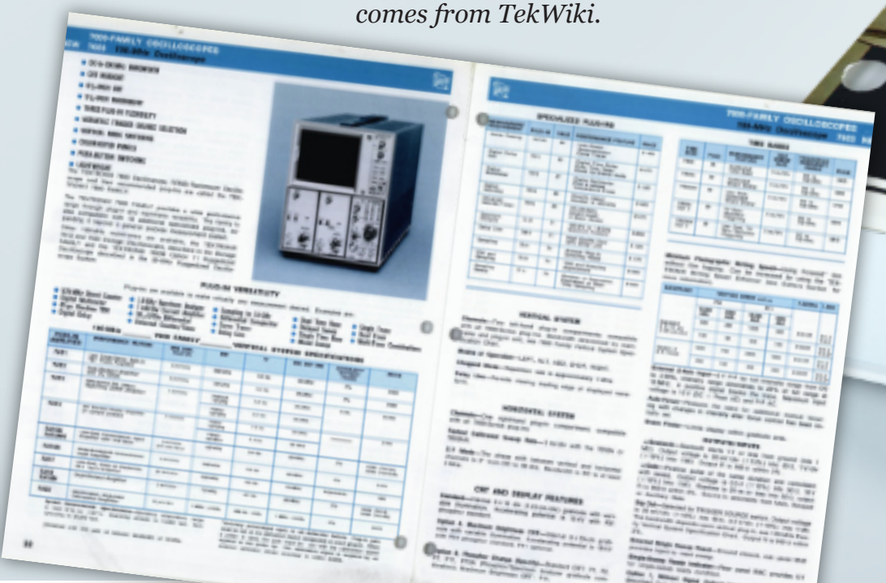
TekWiki & documents

In the first seventies, owning a Tektronix was an impossible dream for many of us. Getting hold of a thick and wonderful Tektronix catalog was not easy, but easier. At that time, documents were precious, not as today that we can easily download them from the net. To have or not to have, that was the point. I remember that I could get, don't remember how, a 1973 catalog. How much I studied it! So much that I consumed its pages and that even now I remember its colors and the smell of the ink.

Today we are so lucky to have a priceless tool called TekWiki (https://w140.com/tekwiki/wiki):

> "TekWiki is a wiki for the community of Tektronix oscilloscope enthusiasts. The purpose of this website is to help people get information about classic Tektronix equipment. There is nothing for sale here. You don't need an account if you just want to read pages and download files."

It is a real treasure trove of information, a true place of delights for crazy people like us. We must thank you, TekWiki, if today we are able to restore that old stuff. A large part of information here comes from TekWiki.



The VintageTek Museum

The enthusiast's vintage Tektronix Valhalla

The ugly duckling & Tek Pride

When, after forty years, I started again tinkering with old electronics outside my work, e.g. collecting old Tektronix scopes, many made fun of me. My wife was even contemplating getting me examined by a doctor: "it is an acclaimed case of accumulative-compulsive mania", she said.

So I tried working silently in the darkness... But then, like the ugly duckling, I started discovering that there were others like me, loving and collecting that old stuff; groups with thousands of members, and even a Museum!

So I changed my attitude, and, being proud of my "diversity", I started writing this book, dedicated to other silly old-aged boys who find fascinating these time capsule from another era.

I reached the top discovering, after Tekwiki and other forums, the VintageTek Museum (https://vintagetek.org), that I will present in the following pages, to to give courage to other ugly ducklings.

The VintageTEK Museum

VintageTEK (https://vintagetek.org) is a charitable, educational and scientific museum founded to commemorate the early history of Tektronix. The museum and website is dedicated to displaying Tektronix products which enabled generations to create the future, and in memory of those employees contributing to this legacy. Let them describe with their own words:

We do not have predefined tours and tailor the experience to the age and interests of the volunteers. The museum is filled with working Tektronix products from about the first 50 years of the company. The tours can focus on many different aspects including the instruments and their uses, the technology that enabled these products, applications in industry and research, individuals that enabled these products, and to stories about the company.

We play company videos specific to products and applications, and history and capabilities of the company. We also have an interactive library for patents up through 2010 and employee photos prior to May 1970.

We have hands-on demonstrations for visitors of all ages and have toured students at age 8 up to seniors. These include sounds, games, computer graphics, music, and science.

Due to the highly interactive nature of the tours, it is best for smaller groups. We typically accommodate larger groups with more volunteers to conduct multiple tours simultaneously. Our regular open hours are updated here on our website but we will strive to accommodate your schedule if a volunteer is available, and admission to the museum is free.

I wish to add few words. I am an entrepreneur, going to retire in one or two years. I started as a student, and now I am old. In my life I hired a number of young people, helping them to grow up whenever I could. I strongly believe that the spirit, the principles of VintageTEK are those that can really help having a long and satisfactory job life. I subscribe them hundred per cent.

E03

TREASURES: three early Tektronix instruments. The Type 101 Video Calibrator on the left is Tektronix first product. Not the same instrument type as the first product, but the exact first product that ever came out of their plant. The serial number is 11461 which translates to November 1946 #1. They produced 10 and none sold. Their purpose was to give the manufacturing line something simpler to start with.

Some VintageTEK treasures

(https://vintagetek.org)

VintageTek Museum

E03

The 7000-Series project key points

Here we will retrace the birth of the 7000-Series, briefly analyzing the many innovative solutions in it implemented.

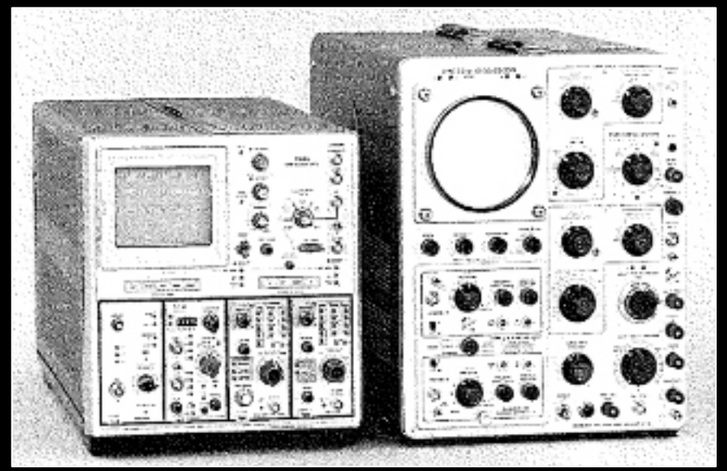
A bit of history

We cannot talk about Tektronix without telling something about its history. As stated, I don't consider myself an expert, neither an Historian, but I could find on the Internet very interesting documents and I couldn't help but trying to tell you what I learnt.

One of the documents I am speaking of is "ON THE HISTORY AND ENVIRONMENT OF TEKTRONIX", some basic information about Tektronix history, instrument concepts, technology, and some overviews of related industries, important customers, and key competitors." (1978)

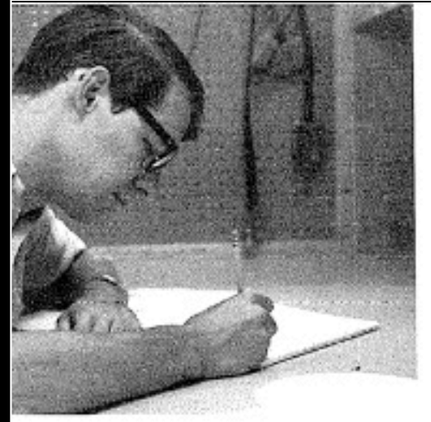
I find it interesting, above all for the spirit that comes out of it: the spirit of many guys with a giant passion for their work, and for the products they were designing and producing. As an old entrepreneur, I strongly believe that a book like that should become a mandatory matter at the university, for all those who want become an engineer. A spirit that is today more and more often forgotten in favor of cold business plans and Excel spreadsheet. And it is for this timeless spirit, that I believe that we should remember the great Tektronix, even before than for the oscilloscopes or market shares.

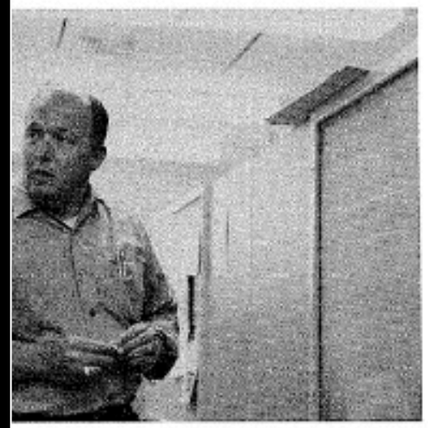
In that book, I could also find situations that I have been living dozen of times in my life. For example, when, in 1966, they had to quickly design the 7000-Series, after a first indifference by the management, with an incredible drag when they learnt that Hewlett-Packard was going to introduce the 180-Series.



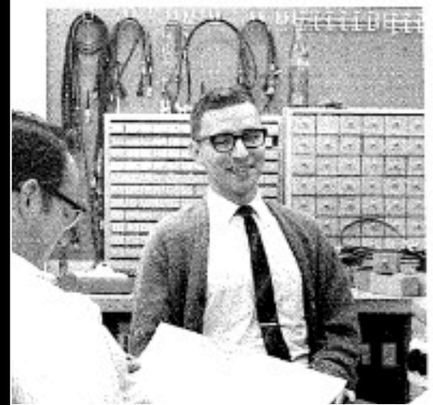
I can imagine the worries, the sleepless nights, the right and the wrong ideas, and all that incredible work that eventually led to those 7000-Series super-successful instruments. Thank you, guys!

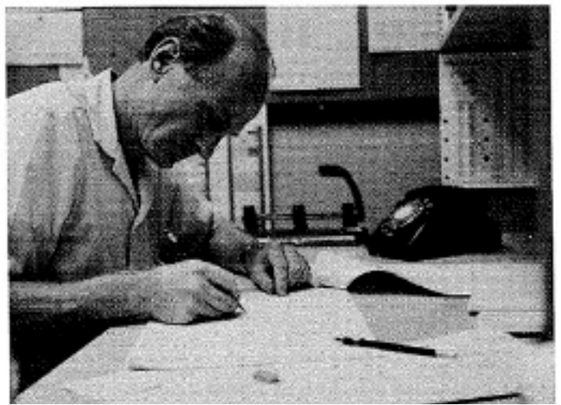
Here some pictures from the Tektronix house organ "Tekscope" of October 1969, where the 7000-Series was presented.

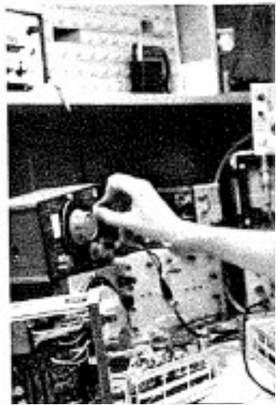




NEW GEN







Performances? only a due act!

Another very interesting document, is the October 1969 issue of Tekscope house organ, where the 7000-Series is presented, from which I will report large excerpts (with different typography, to distinguish them from my notes), to relive the atmosphere of that moment, and to better understand which was the inner approach to these new products and the mental attitude that led to their development.

More than "7000", they used to call them the NEW GENERATION, briefly NEW GEN, a term today used even too often, but that, in this case, was really well suited.

Performances were important: 150MHz and 5mV, were, at that time, relevant figures, but you can feel that performances were, yes, important, but it was just ...a due act! A Tektronix oscilloscope couldn't not have them.

But what that more excited the architects of the new instruments were the absolute novelties that they embodied and that we will try together to retrace in the following pages.

❶ The October 1969 Tekscope issue cover.

❷ As we will see later, performances were obtained also with the extensive use of custom ICs. In the picture, the beautiful interior of the 7A26 popular vertical amplifier, capable of 200MHz BW.

Human engineering

We could call it today "user experience" or "ergonomics", but, at that time, these words had not been coined, so Tek called it "Human Engineering".

As we will state, the new instruments were setting new important challenges: they had to be performing, innovative and rich of functions, but once the choice of plug-in size for the 7000-Series was determined (66W x 127H x 361L mm), it became evident that a new approach was required, not only for the components, but also in the pane logic and layout, if they wanted that the new capabilities could be understood and easily used.

> "As a result of a joint effort between component development engineers, circuit engineers, mechanical engineers, and industrial design engineers, suitable Tektronix components were developed. Once these new components were available, it was then possible to design an instrument front panel considerably different than before. The result is the radically new and logical front panel layouts of the 7000-Series and the R5030.
>
> The miniature lighted push buttons were designed to eliminate function selector switches and rotary switches wherever possible. Rows of miniature lighted push buttons quickly indicate the status of all controls where a choice must be made.
>
> The push-button spacing has been given considerable attention. Since the finger is oval, not round, vertical and horizontal requirements are different. The curvature of the finger and how far you have to push determines the minimum spacing of the buttons. This spacing has been closely calculated and as a result, there is more finger space than is present in commercially available push buttons used in the Type 184. These self-cancelling push buttons are one of the greatest contributors to the simplified front panel logic of these new instruments.
>
> A logical and consistent use of front-panel color coding identifies specific functions and simplifies front-panel logic."

After more than half a century, the 7000-Series oscilloscopes are still beautiful and even more pleasant to use than modern ultra-complex touch screens!

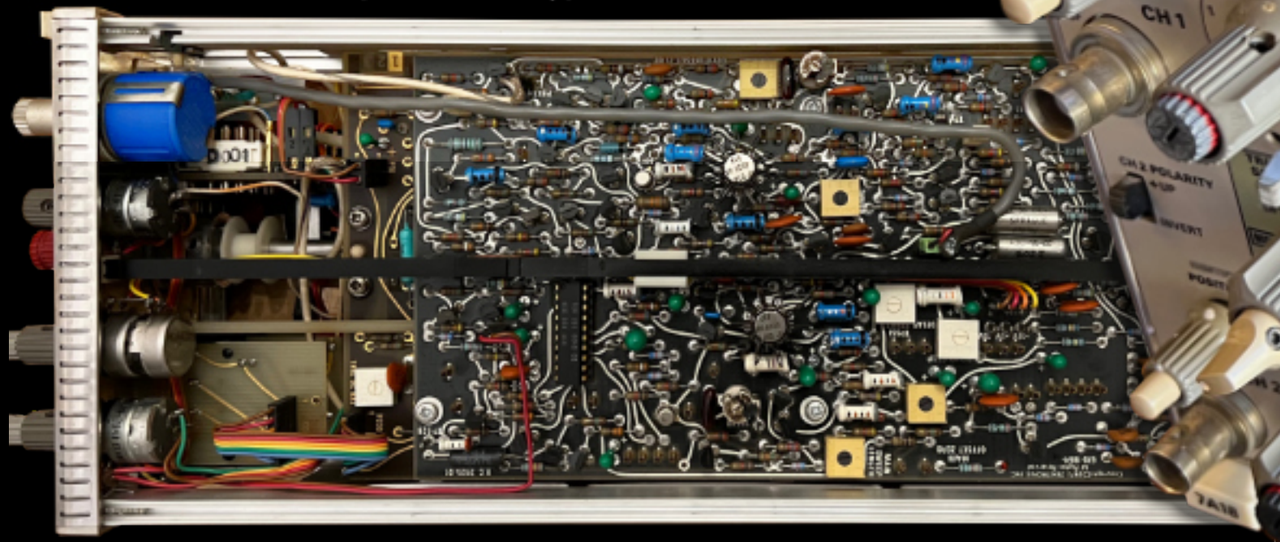
The plug-in winning idea

The plug-in concept was not new, for example it was already present in the old 500-Series, but in the 7000-Series it reached the top, and its intelligent declination was perhaps one of the greatest reasons of the success. At the moment of the presentation, only 13 plug-ins were available, but Tek underlined the the new equipment was designed to be the most expandable line of oscilloscopes ever developed. And it was. More than 65 different drawers were eventually available.

The first 7504 and 7704 had four bays for plug-ins, then reduced to three in the successful 74/76xx models. Horizontal and vertical plug-ins are interchangeable and, as we will see, allow a lot of different modes of operation.

The plug-ins were built very well indeed, and, apart for having to switch off the power, the drawers exchange is almost immediate. We will speak more on them later.

In the photo below, the internal of a drawing (in this case the 7B53A double time base, standard & delaying). The construction is wonderful and allows repairs with not too many problems.



Cathode-Ray Tubes

Tektronix was for CRTs what Stradivari was for violins. For the 7000-Series, they introduced new CRTs, defined "large", that will be furthermore increased with the 7603-Series:

"The heart of any oscilloscope is the cathode ray tube. The ceramic post-deflection accelerator CRT's developed for the Tektronix 7000-Series Oscilloscopes offer significant improvements over CRT's currently available. The 8 x 10cm viewing area provides a large bright display with high writing speed."

An important point, today totally forgotten, was the ability to take photos of the screen:

"Both the 7504 and 7704 can easily record an 8-cm single-shot photo of their rise-time, using standard Tektronix P31 phosphor, without employing film fogging techniques."

Often, technical construction details of the tube were not completely understood by us normal users:

"The new Tektronix CRT's use a frame-grid construction. Frame-grid CRT's employ scan expansion and provide a very good compromise of deflection sensitivity and writing speed. Because frame-grid conductors run only in the vertical direction, electron-beam transmission is nearly 50% greater than most mesh construction tubes. The result is a high writing-speed tube with very good linearity and sensitivity (e.g., the 7704 CRT vertical sensitivity is about 3,3 V/cm) over a full 8 x 10 division scan. Good horizontal sensitivity is achieved by placing the frame grid as far forward as possible into the post accelerator field. This causes the field lines to curve around the front of it sufficiently that the effect on the electron beam is similar to a curved horizontal plane. Thus many of the advantages of a mesh are obtained with few disadvantages. The 7704 CRT is operated at 24 kV and provides a specified minimum writing speed of 3300 cm/p.s (with C-51 camera) using Tektronix standard P31 phosphor with no film fogging. This photographic writing speed is more than twice that of the Type 454 with P31 phosphor."

Attention to user protection is not only from these days:

"The 7704 incorporates a special face plate design to ensure that X-ray radiation is attenuated well below the TV standard recommended by the National Council on Radiation Protection and Measurement (100% duty cycle raster with full intensity). In addition circuitry has been included to limit the maximum possible high voltage to keep the specification well within this figure."

Today the CRT has been replaced by color TFT displays with touch screen, but the magics of the old cathode-ray tube remains unmatched.

Architectural decisions

It is evident that, when designing a modular oscilloscope, you will have to decide where to put the dividing line between the mainframe and the sub-modules, i.e., the plug-ins.

In Tektronix, they decided to keep in the mainframe a large part of the amplification chains, both for the vertical and for the horizontal channels.

"Placing the plug-in interface before the oscilloscope amplifier provides a number of important advantages. For maximum versatility, we have chosen a plug-in output of 25 mV/div at 0 volts in a 50-ohm environment. This convenient interface will allow us to take the maximum benefit of new developments in components and in signal conditioning. In addition, as future oscilloscopes evolve, changes in display sensitivities are easily accommodated with the buffering vertical amplifier.

Although this design choice increases the initial price of the oscilloscope, it decreases the price of each plug-in. With the vertical amplifier in the oscilloscope, it is not necessary to build an output amplifier for each plug-in and this saving may be passed along to the customer."

❶ In all 7000-Series mainframes (in this case the 7923A), the horizontal amplifier stands horizontal, and the vertical stands vertical. Both are very accessible and easy to replace or service.

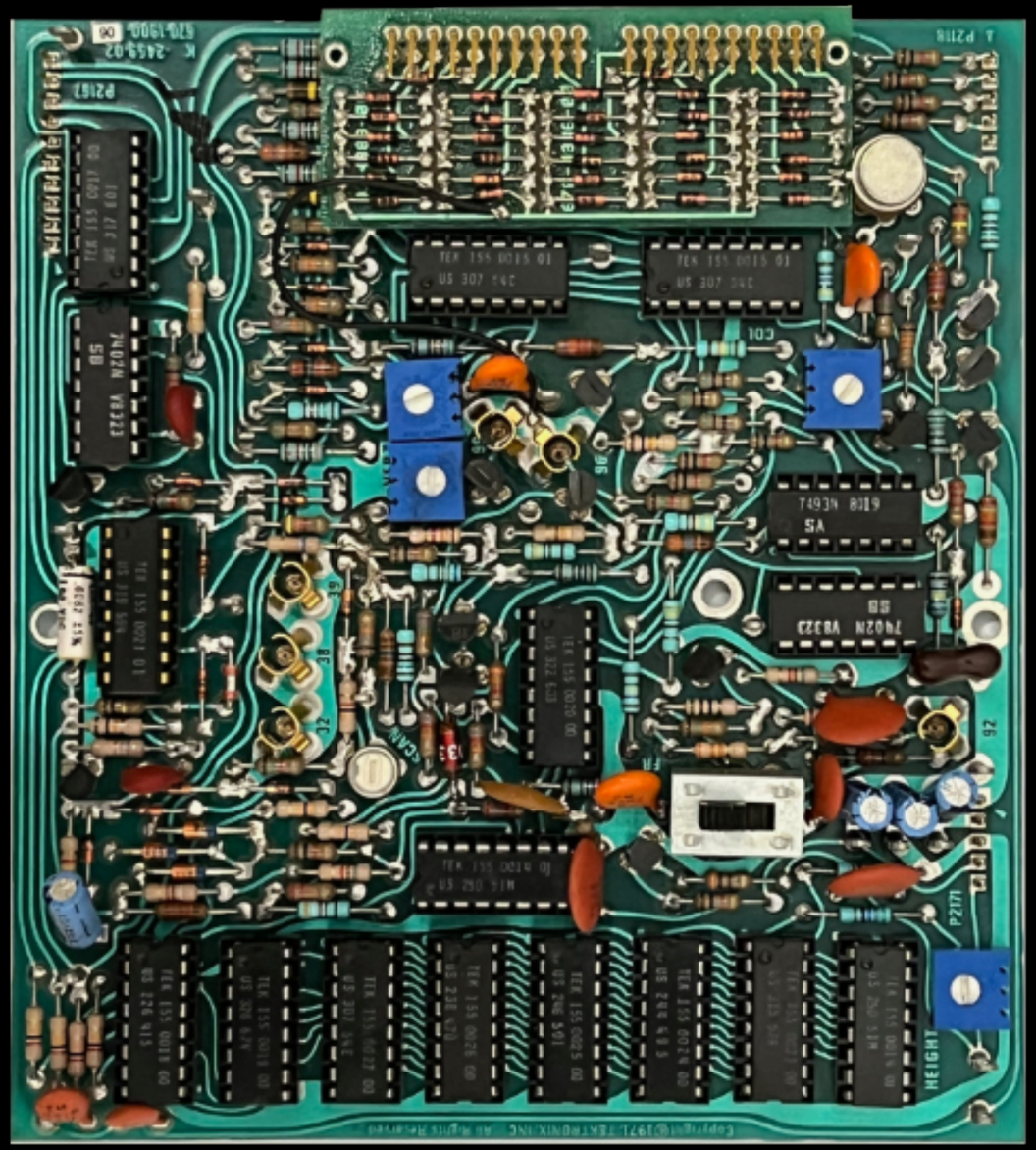
❷ A detail of the 7623A, storage CRT, vertical amplifier. We can understand that the designers had to fight to meet the specifications...

Just press a button

We already talked about ergonomics. The capability to switch from one operating mode to another, thus to ensure an easy and flexible operation, was simply called "switching" by Tektronix.

> "Switching in the 7000 Series is accomplished in the mainframe of the oscilloscope. Five vertical mode push buttons and four horizontal mode push buttons determine which plug-in outputs will be displayed. Twenty possible combinations of vertical and horizontal operating modes are provided for maximum versatility. This design choice allows comparison between any two vertical channels to enable comparison of signals with significantly different characteristics. For example, sampling (50 ohm) and conventional (1 MOhm); wide bandwidth and high sensitivity; differential comparator and current probe; dual trace and dual trace for four-trace operation are all easily accommodated in the appropriate plug-ins. In addition, as higher performance or special performance plug-ins are developed, they may be used with a more conventional unit.
>
> The center two compartments are designed so they may be devoted to sampling capability, spectrum analysis, or X-Y display. This allows a signal to be observed in a conventional manner while simultaneously monitoring a sampling display, frequency display, or X-Y display of the identical phenomenon."

Talking about 7904, we will see more in details some operation modes of a four bay oscilloscope.

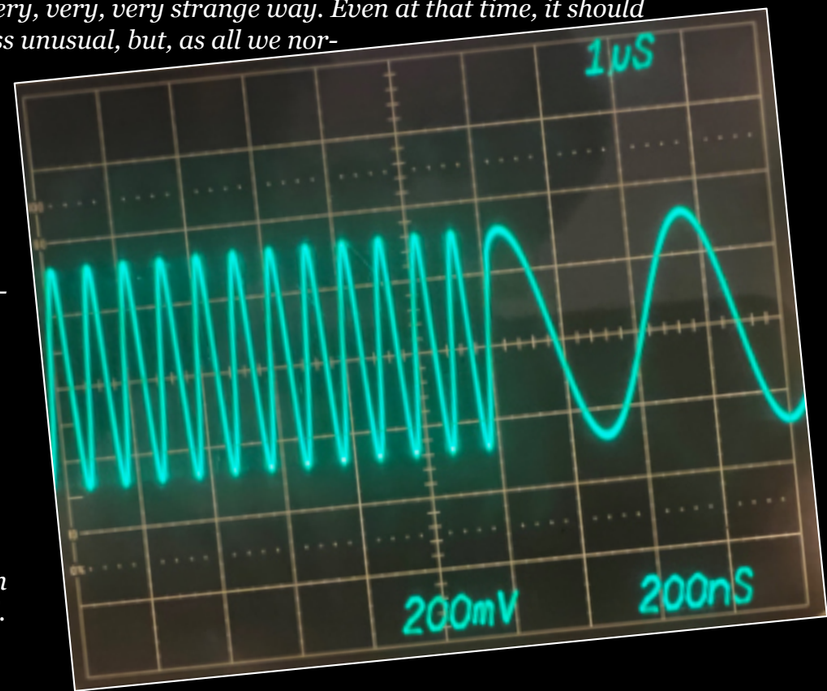


This is not the readout board of 7704, but is the standardized model that equipped 7904 and all subsequent models. It was replaced by a much simpler microcontroller controlled one with 7904A.

The readout
...it can write!

Today we are used to large, perfect, color displays with resolutions so high that we cannot anymore distinguish. But in the beginning of the seventies, I can confirm that anything capable to write something controlled by a machine was absolutely unusual. We used to use Teletypes and even a video terminal was something reserved to science fiction. So, an oscilloscope capable to write alphanumeric text on the screen was an absolute innovation. To do that, Tektronix adopted a solution called "readout", which used the same CRT to show the vertical and horizontal settings and, with special plug-ins, a lot of other things. The shown values were corrected by the probe attenuation value. In the 7000-Series presentation (Tekscope 10/1969), Tektronix defined it "possibly the most dramatic feature of the new instruments", *that everyone will follow in the years.*

How did the readout work? In a very, very, very strange way. Even at that time, it should be possible to design something less unusual, but, as all we normally do, they probably preferred to use the technology in which they were stronger, and so designed an incredible communication system between the plug-ins and the mainframe, based on a pair of 11-levels current values. In other words, every symbol was defined by a pair of current values, and the mainframe "asked" the plug-in a couple for each possible position on the screen.



In this way, on the side of the plug in, it was required not much more than a switch and some resistors.

If you want to know more, you can find more information on TekWiki.

Tektronix components

“The new generation of instruments would not have been possible without the extensive component development program embarked upon by Tektronix component engineers. Early in the program it was recognized that commercially available components would be much too restrictive; so simultaneous development programs were initiated in integrated circuits, rotary and push-button switches, relays, and thick film attenuators. At the same time, efforts were launched in developing the "mother-board" etched circuit board concept along with the required interface connectors.”

In this statement we can see how Tektronix really started from a blank sheet, designing the 7000-Series, open to any possible innovation and setting the pace for the instrument industry for the following decades.

The results of these efforts are the prime factors in the ability to introduce the R5030 and the 7000-Series. For example, auto scale-factor readout would not have been possible without custom integrated circuit design, since the price and size would have been prohibitive.

But the real quantum leap was again in the advanced technology: at the time, when many were still trying to understand how to convert their product lines from tubes to transistors, Tektronix was introducing, in the normal production, its custom designed first integrated circuits:

Much of the versatile switching that characterizes the 7000-Series is also accomplished with custom IC's. Tektronix Integrated Circuits are widely used in new generation oscilloscope circuitry. Seventeen different integrated circuits are included in the new instrument designs and allow performance that would otherwise be unattainable. The ability to custom-design IC's permits instrument features that would otherwise be prohibitively expensive. The ability to use the best logic for a given job, instead of relying on logic designed for other applications, results in a more versatile, logical instrument at a more economical price.

Tektronix ICs are identified by a code starting with 155- or 156-. Most of them are incredibly still now available by eBay sellers at reasonable prices.

Tektronix relays

Tektronix's use of relays stimulate some reflections. Today, you would't use a relay in a project, unless absolutely necessary. Relays have a reputation for being unreliable, too big and in general source of troubles, so I was amazed when I discovered that Tektronix used them liberally in many designs (for example, the 7A13 differential amplifier has as many as 12 of them).

Tek said that

> "Low-capacitance miniature sensitive relays have less leakage than semiconductor switches and are much more tolerant of transient voltages."

I can see, furthermore, other relays' advantages:

- *the possibility to place them where they really are needed, avoiding long and complex wirings toward switches, keeping so the signal paths very short;*
- *an absolute insulation between the managed contacts and the command voltage;*
- *an easy replacement, etc.*

Tektronix bet on relays, but assumed that the market has not an adequate offer of them, decided to design and produce their own:

> "The new Tektronix instruments make extensive use of relays and relay switching. As there were no inexpensive miniature relays on the market, Tektronix engineers developed a 200-mW double-pole, double-throw sensitive relay. From this basic design, there are currently 16 variations including a single-pole, single-throw version, a magnetic latch version, and a bifilar wound center tap latch version."

As usual, also the relays, after ICs and transistors, had their own sockets:

> "Tektronix relays are generally designed to plug into a socket that is flow soldered to the etched circuit board, assuring quick and easy servicing."

Actually, Tektronix relays were designed very well: small, fast and reliable. Most of them, thanks to a very intelligent pin assignment, can also be reversed, i.e. inserted at 0 or 180°.

We will talk again about Tektronix relays, describing some circuits that use them (see 7A13), and giving some tips for their restoration (in the last part of this book). We will also discuss the evolution of the relay design, with the rotary cam switches, surely much less expensive.

New potentiometers

Potentiometers don't escape Tektronix's desire to have a custom design:

A new potentiometer design contributes to operator convenience and saves front panel space. The design uses a 3:1 reduction drive to improve the resolution of the triggering control. By combining this potentiometer with a relay, the slope is automatically changed as the level control passes 0°and 180°. The development of this feature provides a new case in oscilloscope triggering and contributes to the human engineering of the new instruments.

A "push-push" switch design was developed to switch variable controls in and out of the circuit. The small switch, which conveniently solders to a circuit board, is used wherever a variable function might uncalibrate an oscilloscope.

A lucky restoration - One of the worst buy in my collection, was the 7A12 plug-in. It was declared as "used", "in working state", but really had a lot of stuck keys, broken bulbs, and a knob "bent but operating", which had its corresponding multi-turn potentiometer open and destroyed. I gave up hopes to restore it, and I haven't even taken photos of the operation, convinced to get nowhere.

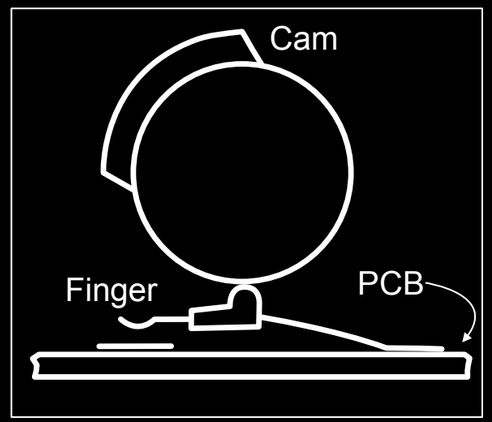
But, with infinite patience, I could eventually close it. To make the repair more robust, I built a "harness" with copper wire, that you can see in the photo on the right. Will it work? Incredible, I succeeded, it works perfectly! A stroke of luck...

Cam switches & push buttons

The earlier plug-ins used relays, especially on the signal path, for example in the attenuators. Maybe that someone in Tektronix asked himself: is there any possible alternative to relays, that are rather expensive and however complex? So, in parallel with the introduction of some solid state switching (e.g. the 155-0022 IC to select or mix two analog signals), a new switch technology was introduced, with the benefits of relays and with also some improvements. As we already reported, Tektronix included among all the components designed for the new scopes, rotary and push-button switches.

> "Tektronix switch engineers developed the small reliable rotary cam switch to replace bulky multi-ganged rotary switches…. This novel configuration simplifies the front panel logic and conserves front panel space. Rotary cam switches provide the following advantages: 1. Lower and more controllable torque…. Thus a smaller diameter knob may be used allowing more efficient use of front panel space. 2. Higher reliability and longer contact life. 3. More accurate control of tolerances since cam manufacturing uses numerically controlled equipment. 4. Wiring to the switch is more direct. "On board" wiring may be used since no separate wiring harness is required."

The relays' advantages were carried a step forward, with lower costs, and the plug-ins had consequently a neater design, with a dramatic reduction of the required wiring.



As we said, also new push buttons were introduced. Most of them could be lighted and are very nice to see (but for untold reasons, they required to add a simple voltage regulator to power the lamps on 76x3 models).

New miniature push buttons indicate the status of various functions and replace many of the larger switches used in previous designs. The basic family of push-button switches is produced in rows of 2 through 10 positions. Most configurations require only one lamp to light any button in a row.

We will talk again of rotary cam switches and push buttons in the section dedicated to restorations, at the end of this book.

The cam switch in a 7A18 plug-in attenuator

Connections

At the end on the sixties, when the 7000-Series was designed, ribbon cables where not an absolute novelty, having been introduced in 1956, mainly for large mainframe computers. But for the rest of us they were still science fiction and most general equipment (e.g. radios or instruments) had them. Tektronix, once again, was a technology forerunner, and used them extensively in its new large project, even though they did not use polarized/guided connectors, requiring very much care by us who try to restore them (a wrong insertion can be destructive).

Did you note that they are color-coded like the resistors? So, brown goes in the pin 1 (or 11, or 21…), while red is wire 2 (or 12, or 22…) and so on. For reason that I don't know, perhaps the cost, at a certain point they started to use white wire, with just a colored stripe. More recently, just the wire number one is marked or none.

Another typical connectors introduced by Tektronix are the PCB coaxial connectors, that you can see on the right page here. They are rather practical and reliable, if you treat them reasonably well. Note, in the photo, also the transistor sockets.

Power supply

The 7000-Series oscilloscopes use a lot of supply voltages: +50V, -50V, +15V, -15V, +5V, +130V (and the storage models also 600V). Designing today a power supply unit like that it's rather easy, because the market offers a lot of different solutions to build inexpensive and highly efficient switching regulator. But, at that time, you had almost no choice, if not using linear regulators. Also this was going to change, in Tektronix willings: the 7704 had a new switching regulator (called "high efficiency"):

> The 150-MHz 7704 utilizes a "high efficiency" power supply which eliminates the bulky iron-core transformer and heat sink and eliminates any necessity for a fan. This new supply dissipates approximately 60 watts compared to 140 watts that a conventional supply would dissipate. Use of this new supply removes approximately 12 pounds from the weight of the instrument, providing a 200-W power supply in a 10-lb package.

I must add that I made things simpler than they are: if designing a circuit to produces the above voltages is today rather easy, much more difficult is to produce the 25kV necessary for the CRT. The NEW GEN design was really rational: with the new design, just one transformer was required, even for the HV.

The 7704 remained however, I believe, an isolated experience. In the subsequent 1971 7904, the PSU was redesigned, condensing part of the circuit in a new Tektronix IC (155-0067), perhaps for cost and service reasons (that IC is today very rare and expensive).

In 1972 76x3, the high efficiency design was set aside, returning to "the bulky iron-core transformer and heat sink", perhaps having also a plug-in less to feed. The fan became available as an option, but was standard for the storage scopes such as 7613/23/33. Servicing these 76x3 machines is not too difficult, even if I have no clear why they used a so complex design, where any voltage is in some way dependent from some other.

Photo on the right, 7904 PSU, courtesy of LAZY ELECTRONS.

Construction

The new instruments made use of front and rear panel castings connected by aluminum extrusions. An incredibly simple solution, light, robust and rational that gave no problem in all these years.

"The oscilloscope plug-in compartment is designed with no dividers for maximum future flexibility. The modular power supplies are located behind the plug-in compartment on cables for easy access.

Plug-in construction consists of a front casting, aluminum extrusions top and bottom, a plastic rear panel, and a circuit board. The central "motherboard" contains the circuitry and forms the connector of the plug-in. This connector then plugs into the female connector at the rear of the plug-in compartments and provides the interface to the oscilloscope amplifiers. The circuit board connectors have been specifically designed for low insertion and withdrawal forces to provide a reliable connection with long life characteristics.

Extensive use is made of new 0.025 square gold-plated pins. Female clips on the end of wires clip directly to the gold pins. Where possible, plastic clips containing multiple connectors group wires together for easier servicing. The use of long pins permits stacking of boards when component density is high. This technique provides good accessibility and case of maintenance and contributes to a neat overall instrument appearance. The format also provides for easier automatic pretesting and faster instrument assembly.

Gold-plated glass epoxy circuit boards are used to ensure maximum reliability. Features such as plated-through holes, built-in test points, and transistor and IC sockets all combine to enhance maintainability.

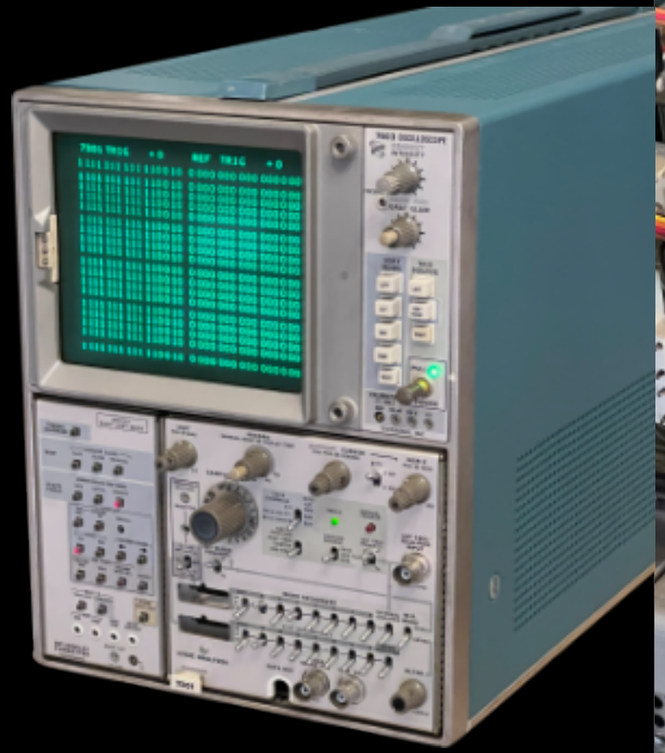
Electromagnetic Interference requirements have been taken into consideration and are a standard feature in the plug-ins."

Simple, inexpensive and effective, the construction of the 7000-Series was a real success. In the photo the 7904, but 7704 was very similar, and so they were all the subsequent models.

The piggyback approach of the boards is nice but, even if they separate quickly, remounting them is not always straightforward and requires often a large amount of patience.

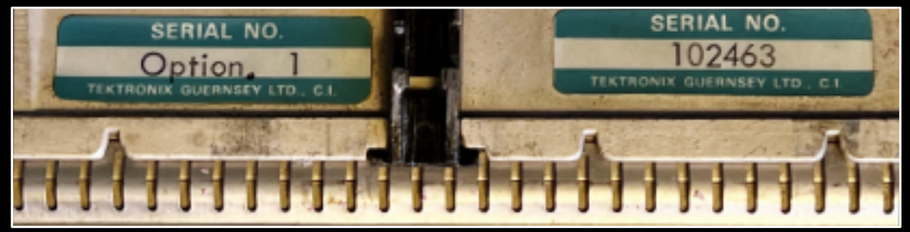
Negative options

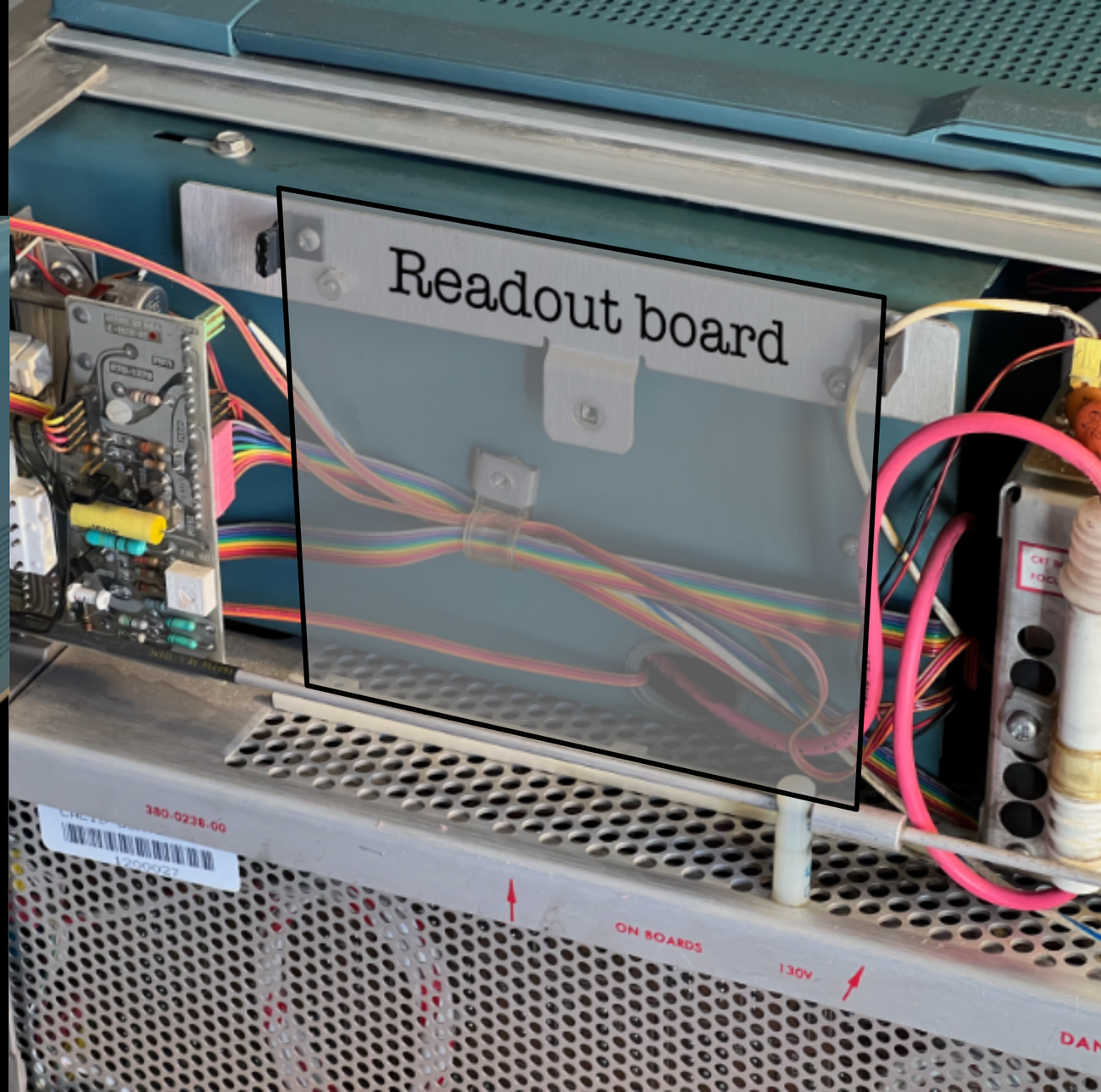
When I purchased my first 7603 oscilloscope, I brought it home and started cleaning it. In the plug-in compartment, Tektronix places the serial number and the option labels. Which kind of wonderful option could be "Option 1"? After finished the cleaning operations, I went on line to learn something more about this "Option 1", and I had to remain disappointed... The "Option 1" is a "negative option", i.e., says that this unit was not equipped with the readout system, that was one of the things I liked more.



I learnt then that this practice of negative options was rather frequent for Tektronix, opposite to the car consuetude of the optionals. It was perhaps a way to entice the users to buy the full feature instrument. It was also a form of correctness toward the customers, confirmed by the fact that, when possible, Tek offered the possibility to add the missed option at a later time (see on the right the provisions for the readout board in my 7603).

What better use, then, for my N°1 7603, than hosting the 7D01F logic analyzer plug-in, that has its own readout system?





Prices

It is rather interesting to look at the Tektronix prices (in dollars) in the years between 1970 and 1980. I don't pretend to be a deep analyst, so I just express some personal thoughts, limiting myself to the equipment described in these pages and taking advantage of the Tektronix's appreciable clarity in indicating prices for each item in their catalogs.

The first thing that I observe in the table is that, in those eleven years, the inflation had been high; as a consequence, the prices were noticeably increasing.

It seems that Tektronix tried to compress the price of 7603, the winning weapon of universal use. In 1973, the 7904 costed 1.8 times the 7603, but in 1980 the ratio was increased to 2.7, with the 7904 touching as much as 6,265$. Perhaps, they wanted also to increase the gap between these two products, to avoid market overlapping. The dual beam 7844 was really a dream machine: about four times the price of the 7603, while for the first 7000-DSO 7854, in 1980, you needed another thousand!

Very interesting the short life of the 7A12 amplifier, introduced together with the 7000-Series. It seems to confirm that the original design, based on relays attenuators, was not so reliable (but I don't think so) or was too expensive. The introduction of 7A18, in 1971, was still not enough to allow to discontinue the 7A12 (75MHz vs. 120MHz), whilst eventually the 7A26, in 1974, made possible to retire the relay-based 7A12, marking the victory of the less expensive cam switches.

Also interesting the long life of the 7A13 and 7A22 differential amplifiers, that however doubled their dollar price in 10 years, despite the general reductions of technology products.

Remarkably high the prices of CRT storage mainframes; probably, Tektronix could capitalize its advantage over its competitors, before the DSOs arrival.

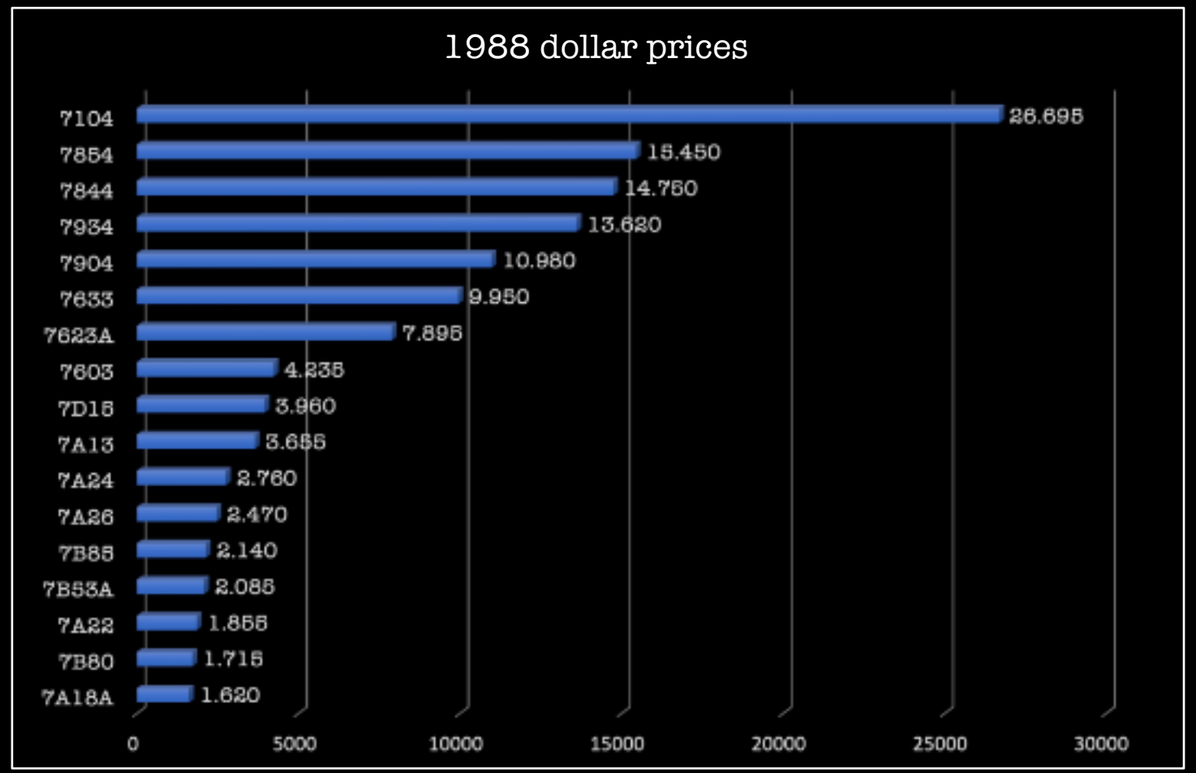
I finally note that the new digital 7D15 and 7D01 plug-ins were really expensive, respectively one and two times the price of the 7603: the innovation had a price.

1970-1980

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Mainframe											
7904				2,900	3,400	3,400	4,100	4,500	5,250	5,695	6,265
7603				1,600	1,600	1,600	1,800	1,850	2,050	2,260	2,260
7623				2,850	2,850						
7623A						3,000	3,500	3,750	3,975	4,295	4,295
7633						3,650	4,200	4,725	5,200	5,615	5,615
7844					5,900	5,900	6,100	6,800	7,650	8,295	9,525
7854											10,500
Plug-in											
7A12	700	850	850	900							
7A13	1,100	1,100	1,100	1,250	1,250	1,250	1,495	1,695	1,900	2,050	2,050
7A18		535	535	535	535	535	615	750	850	915	915
7A22	500	500	500	575	575	610	715	875	975	1,060	1,060
7A24					1,050	1,050	1,150	1,250	1,450	1,560	1,750
7A26					1,050	1,050	1,150	1,200	1,325	1,435	1,525
7B70	600	600	600	625	625	675					
7B53A				850	850	850	925	975	1,050	1,135	1,135
7B80							725	745	875	945	1,000
7B85							875	895	1,025	1,120	1,200
7D15				1,475	1,475	1,475	1,600	1,825	1,850	2,000	2,200
7D01F								4,390	4,390		
7D01F2										5,450	5,450

The most expensive

On the left, a second table, with prices also of some years after the 1980. The blue means "in production". Here below, the ranking of the 1988 prices, where we can have a look of the most expensive mainframes ever in the 7000-Series. The absolute winner is the 7104, the 1GHz-version of the 7904, Interesting the prices, in the same range, of the hyper-technological 7854, the dual-beam 7844, and the fastest CRT-storage 7934. The 7904 is "only" almost 11,000$, while the 7603 seems absolutely cheap, with its 4,235$!



1981-1991

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Mainframe											
7904			8,510		(A)9,405			10,980		12,750	
7104			20,160		23,580			26,695		29,995	
7603			2,700		2,955			4,235		4,235	
7623											
7623A			5,950		6,725			7,895		8,900	
7633			7,765		8,950			9,950		10,500	
7834			11,705		13,365						
7934								13,620		15,100	
7844			12,665		14,750			16,595			
7854			13,750		15,450			15,275		17,000	
Plug-ins											
7A13			2,865		3,240			3,655		3,874	
7A18A			1,180		1,305			1,620		1,790	
7A22			1,500		1,705			1,855		2,260	
7A24			2,225		2,530			2,760		3,075	
7A26			1,910		2,240			2,470		2,750	
7B53A			1,430		1,565			2,085		2,500	
7B80			1,335		1,580			1,715		2,080	
7B85			1,605		1,815			2,140		2,400	
7D15			3,020		3,410			3,960		4,400	
7D01F			6,700		7,550						
7D01F2			7,250		8,150						

7000-Series key points

Mainframes

For Wikipedia a Mainframes is a computer used primarily by large organizations for critical applications like bulk data processing.... *But for us, it is just a place where to put the marvelous Tektronix plug-ins....*

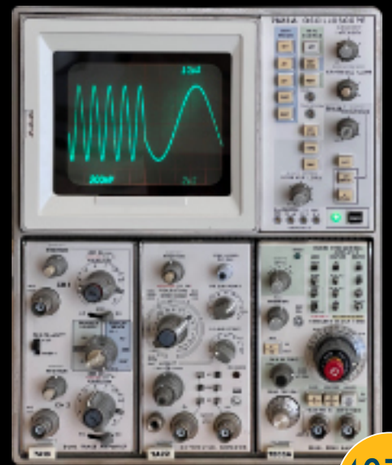
1972

7603

1971

7904

Conventional scopes



1973

7623A

1974

7633

CRT storage scopes

Mainframes

in this page the mainframes which we will deal with in the following pages

1974

R7844

Dual-beam scopes

E03

1980

7854

Digital storage scopes

The clandestine

I am not a member of the 7000-Series but I have friends here...

1972

465

We'll talk about them also

We will talk also about some other Tektronix oscilloscopes that are not part of my small collection, but that are too important not to mention: the 7704, the progenitor, the 7834/7934, the fastest CRT storage technology oscilloscopes and the 7704A+P7001, the DPU, Digital Processing Oscilloscope, one of the first form of Digital Storage Oscilloscope.

For those who are not familiar with the 7000 line of products, the situation may seem intricate, but we are talking basically about just ***one model****, declined in many variants.*

Besides performances, the major differences are among 3- or 4-bays mainframes (yellow in the table) and the non storage or storage CRT technology (dark red).

Model	Year	Type	Band-width	CRT size cm	Accel. kV	Plug-in bays	Watt max.	Fan	Weight (kg)	Writing speed cm/µs	Storage
7704	1969	Modular	250	8 x 10	24	4	180	No	13.6	400÷15,000	No
7904	1971	Modular	500	8 x 10	24	4	190	No	14.1	400÷15,000	No
7844	1974	Modular	400	8 x 10	24	4	235	Yes	16.3	850÷1,700	No
7854	1980	Modular	400	8 x 10	24?	4	230	Yes	20.4	n.d.	No
7603	1972	Modular	100	9,8 x 12,2	15	3	180	No	13.6	n.d.	No
7613	1973	Modular	100	8 x 10	8.5	3	180	Yes	13.6	4.1	Yes
7623	1973	Modular	100	8 x 10	8.5	3	180	Yes	13.6	100	Yes
7633	1974	Modular	100	8 x 10	10	3	180	Yes	13.6	135	Yes
7834	1977	Modular	400	8 x 10	12	4	215	Yes	16.1	2,500	Yes
7934	1987	Modular	500	8 x 10	12	4	230	Yes	17.4	4,000	Yes
465	1972	All-in-one	100	8 x 10	18	NA	75	Yes	10.3	n.d	No

Main models comparison table

7704

7834

7934

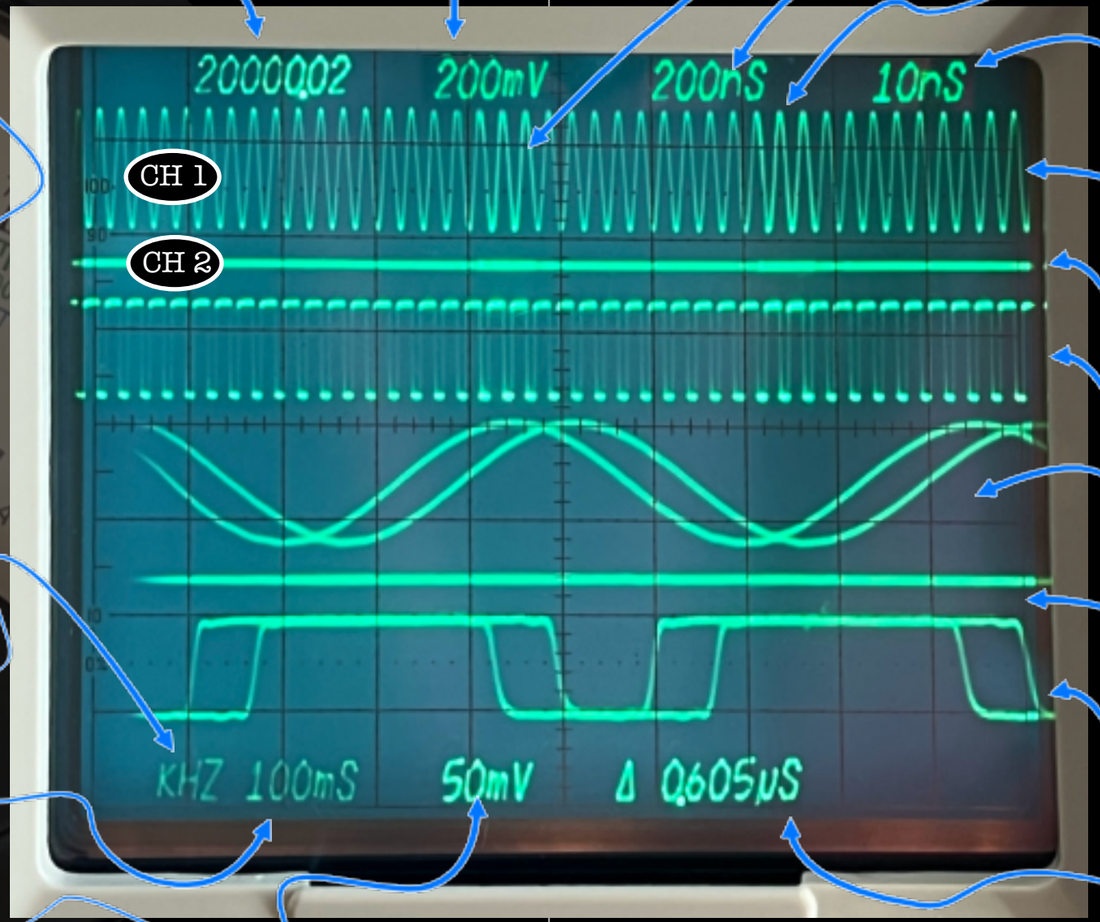
7704 + P7001

How much information!

As more times noted, at the beginning of the sixties, very few equipments were able to present information digitally and electronic labs were full of instruments which gave their results with an analogical quadrant.

The 7000-Series was an exciting news, and its screen was used for more and more applications which used the display for giving the results of the measure.

In this page, a sample with many data all together on the 7904 CRT.



- CH 1 volts per division
- CH1 frequency (by 7D15)
- 7D15 unit of measure
- 7D15 gate time for frequency measurement
- CH 2 volts per division
- First enhanced zone
- Delaying time base (A) V/div setting
- Second enhanced zone
- Delayed time base (B) V/div setting
- CH 1 trace, a sinusoidal wave
- CH 2 trace, nothing
- 7D15 plug-in trigger output, used to understand if we are measuring the frequency in a correct way (see the 7D15 part for more information)
- Enlarged first enhanced zone
- Enlarged second enhanced zone
- Enlarged 7D15 trigger out. Not very interesting...
- Delay between first and second enhanced zones

All the measurement here presented are performed using a Marconi 2022E signal generator, which has a 50 ohm output impedance.

To match the generator output impedance, a 50 ohm terminator is used on the oscilloscope side (the cylinder that you can see in this photo.

Note also the presence of the timer/counter 7D11 plug-in, that produces the digital frequency readout that you can see in the upper left corner of the CRT photos. They have been a bit "tricked" to cancel the effect of the cables and of the 7D11 itself, which otherwise could alter the effective oscilloscope bandwidth.

Bandwidth & rise time

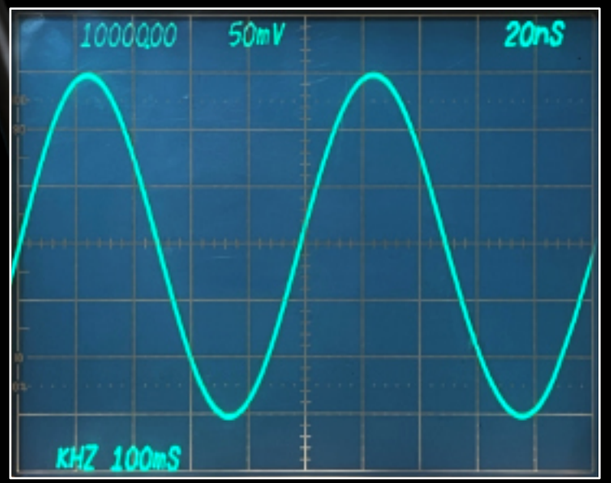
Bandwidth

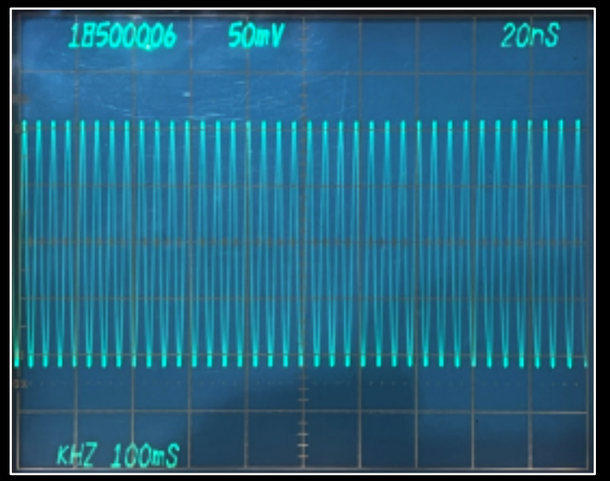
*Even the beginners in electronics, know that the **bandwidth** is an important parameter in the oscilloscope's choice, although some of them have not a clear idea of its meaning. A doubt that I had a million years ago was: why my 10 MHz oscilloscope cannot correctly represent a 10 MHz square wave? To understand this, we need to better define the bandwidth concept: it is the frequency of the sinusoidal wave that can reproduced on the scope with a maximum amplitude error of 3dB, i.e., with an amplitude not less 70.7% of its real amplitude. For example, if you set your scope for displaying a low frequency sine wave to 6 divisions on the CRT, and with a 100 MHz sine wave the amplitude on th screen drops down to 4.2 divisions, that scope has a bandwidth of 100 MHz. We assumed that the bandwidth starts at zero Hz, i.e. that the oscilloscope can operate in DC.*

(To answer my ancient question: a square wave contains a fundamental sine wave and an infinite sum of its harmonics. Thus, the fidelit of the square wave trace on the CRT is as much better as the number of the harmonics that the oscilloscope can correctly reproduce. No oscilloscope on earth can reproduce an ideal square wave, with its content of an infinite number of harmonics.)

Measuring bandwidth

Measuring bandwidth is rather simple, if you have a proper signal generator. Start with a frequency that you are sure that is reproduced with fidelity, and set the size of the trace on the CRT to, e.g., 6 squares. Then increase the generator frequency until the trace on the CRT is reduced to 6 x 70.7% = 4.2 divisions. That is the bandwidth value.





Rise time

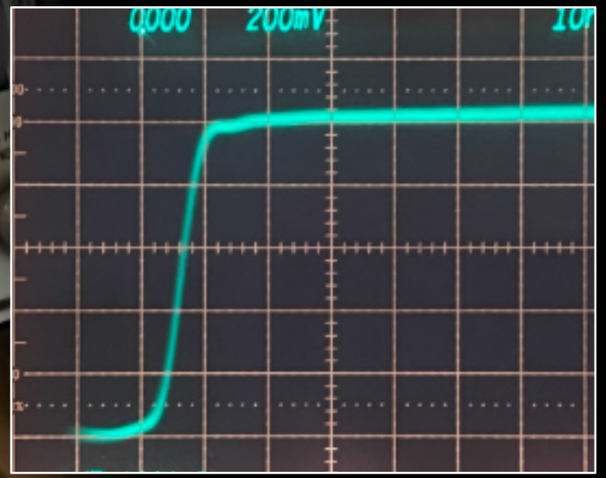
*More than about bandwidth, experts talk about **rise time**. Rise time is defined as the time required for the trace to move from 10% to 90% of a rising waveform. In a well-designed general-purpose oscilloscope, bandwidth and rise time are related by a 0.35 factor, as specified by Tektronix documents of that time (today in DSOs, things are a little different).*

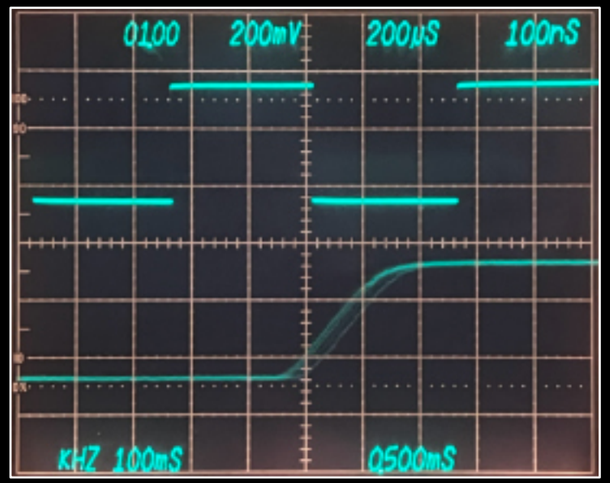
In other words, bandwidth in megahertz multiplied by rise time in nanoseconds is approximately 0.35. Therefore dividing one by 0.35 will produce the other.

According the above concept, a 500 MHz sine wave has a rise time of 700ps, so it can be reproduced by a scope with 0.7ns rise time.

Plug-in	Decl. BW	S/N	Chan.	7904	7603	7623A
MF BW				500	100	100
7A26	200	370	1	195		105
7A26	200	370	2	200		125
7A26	200	042	1	185	90	
7A26	200	042	2	200	90	
7A26	200		2	215		
7A18	75	651	1	195	75	120
7A18	75	651	2	190	80	120
7A18	75	087	1	130	75	
7A18	75	087	2	125	75	
				BW		
465	100		1	140		
465	100		2	140		

In this table you find the measured bandwidth value (in MHz, rounded to 5) for some **plug-ins** of my collection, installed on three different **mainframes**. In the lower part, the bandwidth value for the **465 oscilloscope**. Most values are equal or better than the Tek specification. Surprising the performance of the 7A18 in 7904/7623A mainframes.

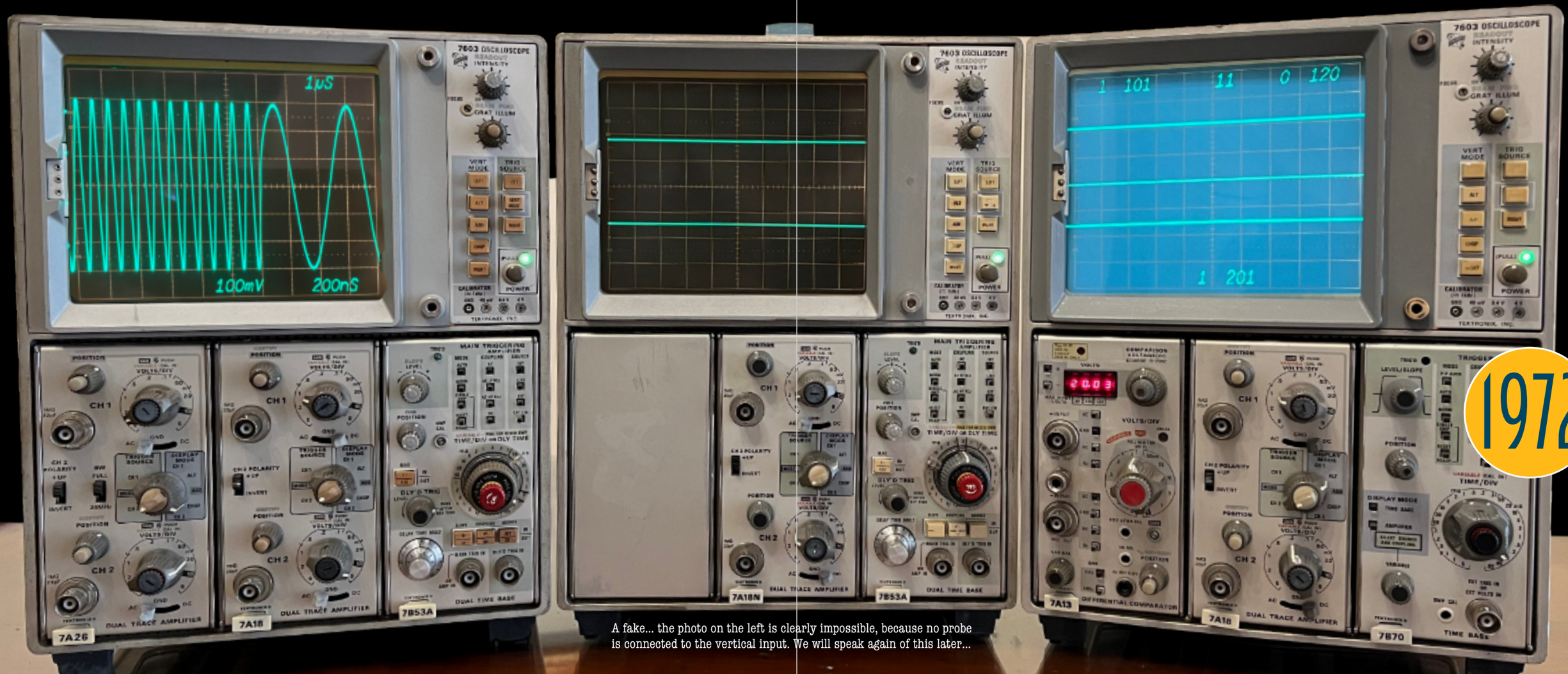




The rise time is not only on the oscilloscope side, but also on the signal generator side. In the above picture you can see the ≈10ns rise front of a Picotest G5100A signal generator, made visible thanks to the 7904 delay line. As shown, each division is 10ns, thanks to 7B80 time base. On the right, a similar measure done on the 7904 calibrator, using a different technique, with the 7B85 delaying time base. The front is much less steep (≈200ns) and less stable. Note the frequency display on the left upper corner, and the delay value from the 7B85 on the lower right.

The beautiful Tektronix 465 showing a 140 MHz sine wave, with a stable, neat and very bright trace. The sweep rate is 50ns/div, but, as visible, the X10 button is pressed. Each division is so 5ns and the period of the wave is ≈7ns.

7603, the most successful



1972

A fake... the photo on the left is clearly impossible, because no probe is connected to the vertical input. We will speak again of this later...

Exactly what the market was asking for

Exactly what the market was asking

At the beginning of the 7000-era, the three bay 7503 had not large success, and remained in catalog only for two years. Things were going to change radically in 1972; the market was hungry of a smaller, lighter unit, and the arrival of the 100MHz 7603, a general-purpose 100 MHz oscilloscope, was an incredible success (as proved also by some strange guy writing of it after more than half a century).

When released, it costed 1,600$, that become 3,520 when purchased together a 7B53 and 2 x 7A18; more than 20,000$ today. It remained in production for 18 years (1972-1990).

The 7603 had a very large screen with an extraordinary CRT. The graticule was engraved directly in the screen, eliminating the parallax-error, typical on the instruments of that time, and had as well the fabulous readout system.

Above all, it offered the flexibility of the plug-in system. As I told, I had the opportunity to use a 7603 as an university student, and it remained for me the absolute top-dream oscilloscope.

They can be still now rather easily found on eBay. Instead of paying a lot of money for like-new units, restoration can be a valid alternative and a pleasant activity.

Simplified block diagram

A basic block diagram of the 7603 is shown in the next pages. In principle, it can be applied as well to almost all other 7000-Series mainframes.

***Vertical signals** to be displayed on the CRT are applied to the Vertical Interface circuit from both vertical plug-in compartments. The Vertical Interface circuit determines whether the signal from the left and/or right vertical unit is displayed. The selected vertical signal is then amplified by the Vertical Amplifier circuit to bring it to the level necessary to drive the vertical deflection plates of the CRT.*

***Horizontal signals** for display on the CRT are connected to the Horizontal Amplifier circuit from the horizontal plug-in compartment. The Horizontal Amplifier circuit amplifies this signal to provide the horizontal deflection for the CRT.*

*The **internal trigger** signals from the vertical plug-in units are connected to the Trigger Selector circuit. This circuit selects the trigger signal which is connected to the horizontal plug-in unit.*

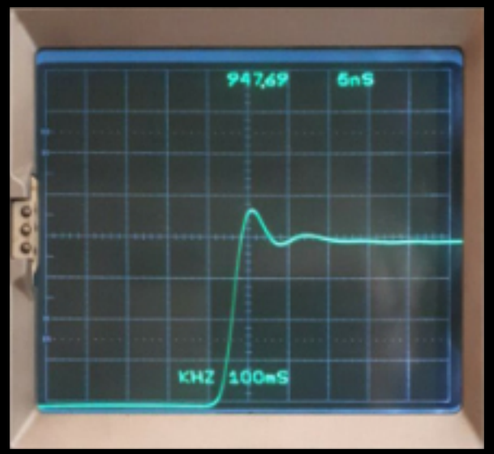
*The **Calibrator** circuit produces a square-wave output signal with accurate amplitude which can be used to check the calibration of this instrument and the compensation of probes.*

*The **Logic circuit** develops control signals for use in other circuits within this instrument and the plug-in units. These output signals automatically determine the correct instrument operation in relation to the plug-ins installed and/or selected, plug-in control settings, and 7603 control settings.*

*The **CRT circuit** produces the voltages and contains the controls necessary for operation of the cathode-ray tube. It also contains the Z-Axis Amplifier which provides the drive signal to control the intensity level of the CRT display.*

*The power necessary for the operation of this instrument is produced by the **Rectifier Board** and by the **Low-Voltage Power Supply circuit**. These voltages are connected to all circuits within the instrument.*

*The **Signals Output** board produces some signals, made available on the rear panel of the unit, that can be used for special applications. See the pages "7603 B-side", below.*



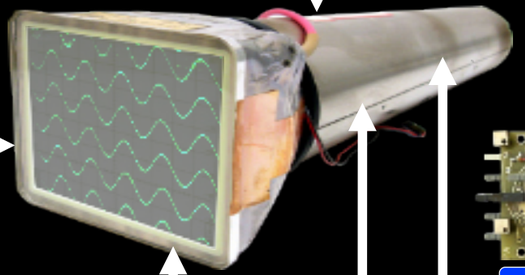
The latest units had a different, microprocessor based, readout board, that had a better and more modern "calligraphy".

7603 oscilloscope block diagram

Vertical interface

Vertical amplifier

High voltage



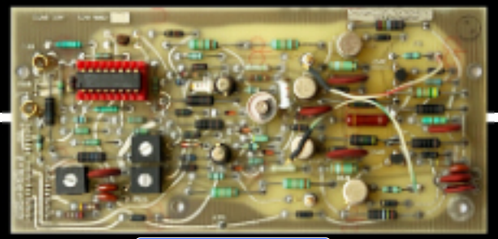
Calibrator

Trigger selector

Readout

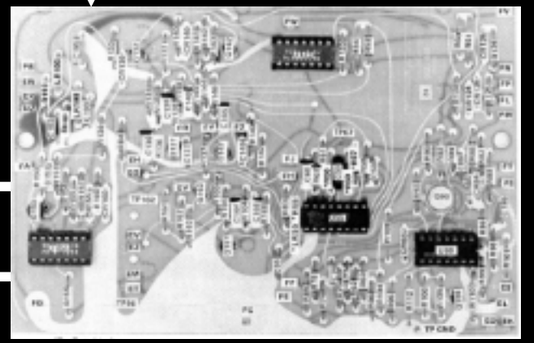
Signals output

Z-axis amplifier & CRT circuits

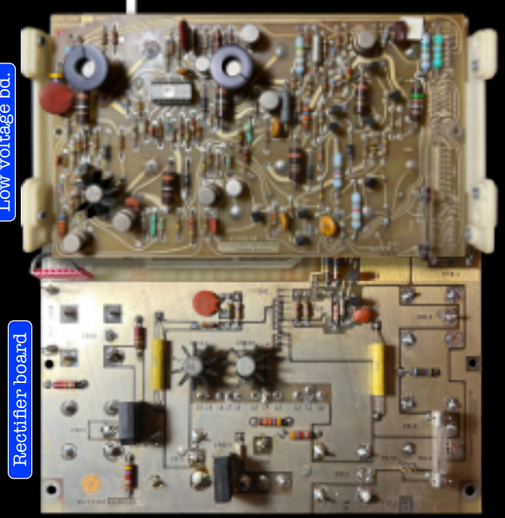


Horizontal amplifier

Note: the boards are not reproduced to scale



Logic circuit



Low voltage bd.

Rectifier board

Power supply to all modules

(plug-in compartment)

Vertical signal from vertical plug-in compartment

Readout settings from plug-ins

Trigger signal from vertical plug-in compartments

Trigger signal from horizontal plug-in compartments

Horizontal signal from horizontal plug-in compartment

Main interface board

Operating data from all plug-in compartments

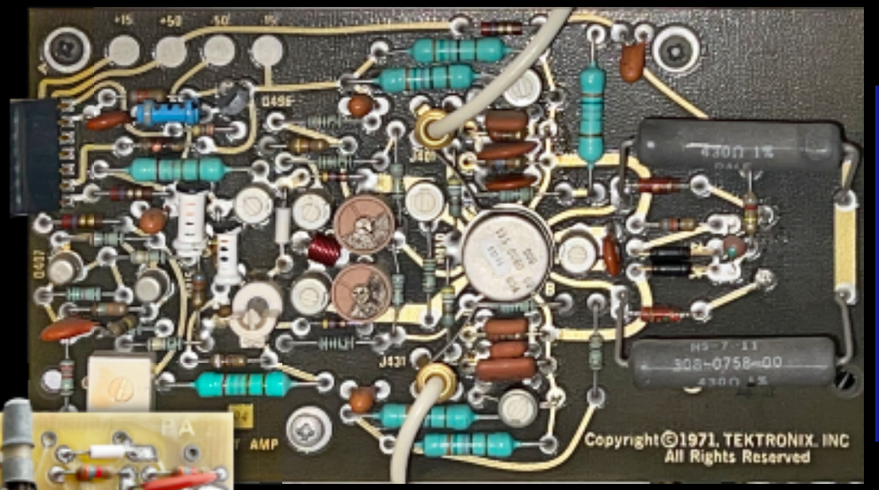
Control signals to all plug-in compartments

7000-Series mainframes

7603 some boards

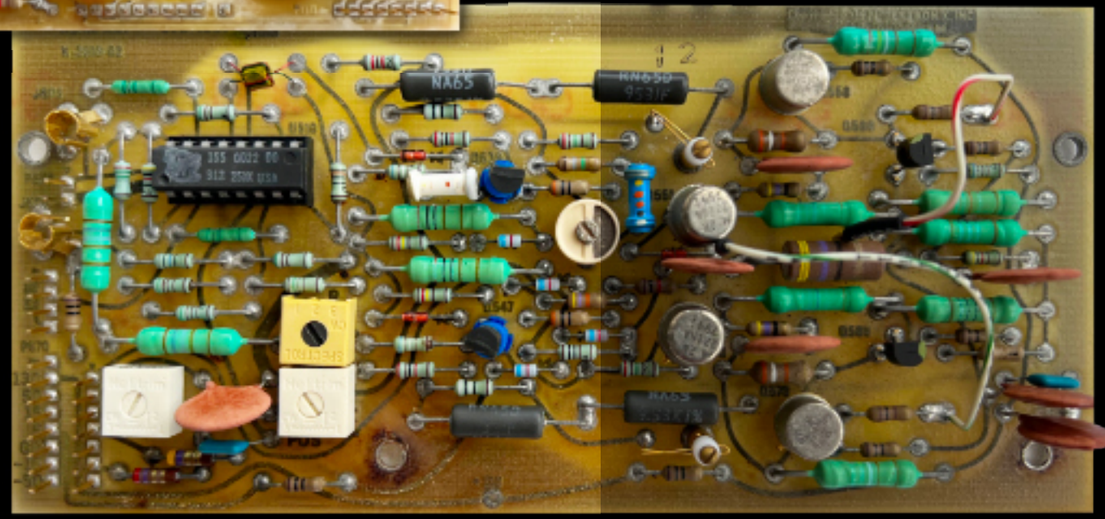
Rectifier board

Vertical amplifier



Z-axis amplifier

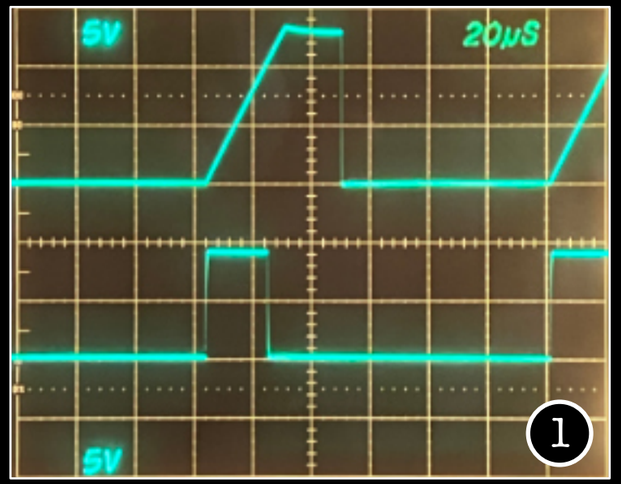
Horizontal amplifier

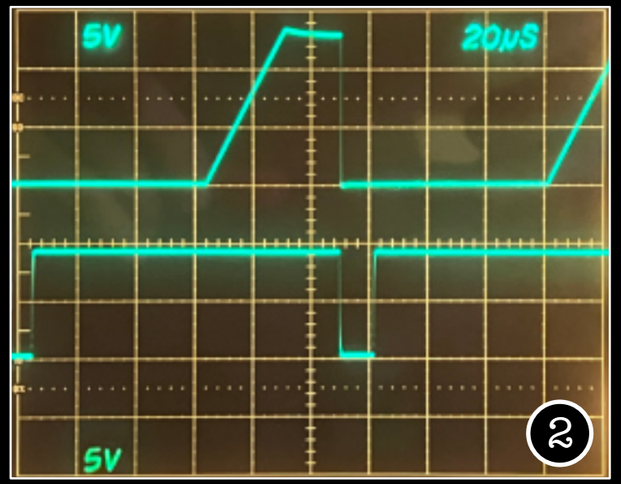


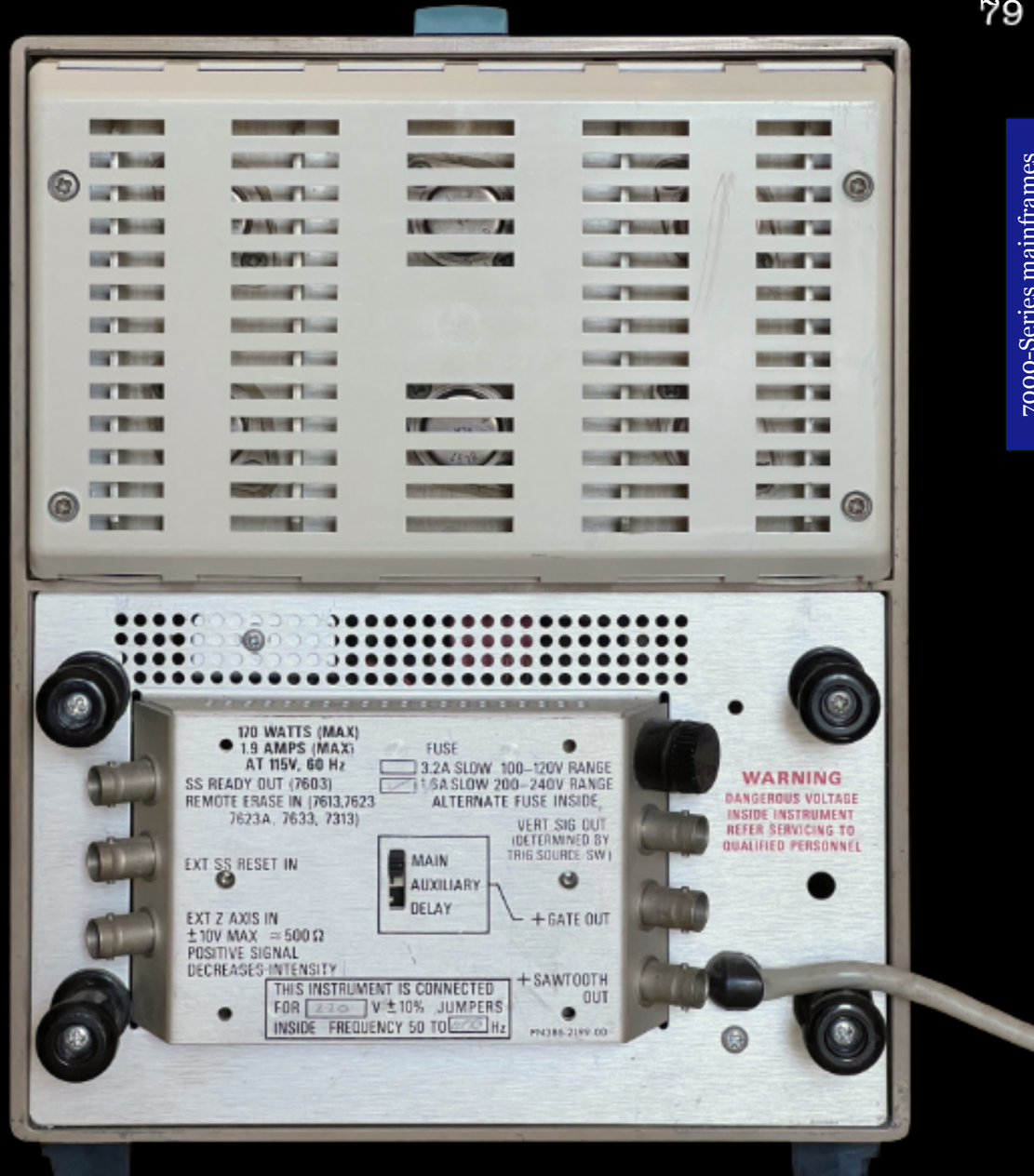
7603 B-side

There are a lot of photos with the front view of the 7603, but few of its rear side. It presents 6 BNC connector, whose function is written on the panel itself, but some notes are required, because they are not very clear and also the manual is rather vague and I wanted to test each of them.

- *SS READY OUT: this active-high signal (0-4V) becomes active for about 5ms when you press the single-step reset button;*
- *EXT SS RESET IN: closing to ground this input has the same effect as pressing the single-sweep reset button. In storage scopes, it erases the memory;*
- *EXT Z-AXIS IN: it works exactly as written on the panel. Negative voltages make the trace brilliant, positive dampen;*
- *VERT SIG OUT: this signal is proportional to the waveform displayed on the screen, 500mV (on 1 MOhm) for each division, ±20%;*
- *+GATE OUT: this is the less clear signal. In general, it stays at the high level (10V ±10% on 1 MOhm) when the sawtooth ramp is increasing. Its behavior depends on the position of the MAIN/AUXILIARY/DELAY switch:*
  - *MAIN: the signal remains high only for the sawtooth duration (inclined section, photo ❶);*
  - *AUXILIARY: the signal remains high for the scan duration, i.e. the delay time (if any) plus the the sawtooth (photo ❷);*
  - *DELAY: I could find no signal on this connector, so I studied the manual and I discovered that this signal comes from pin B9 of the horizontal plug-in bay on the right. But the 7B53A time base leaves this pin free... so, no wonder!*
- *+SAWTOOTH OUT: this is the signal that moves the electronic brush horizontally (the upper trace in the pictures below). Note the 5 V/div, the amplitude is about 12,5V (nominally 50mV/unit time, referred to Time/Div setting, on 1 MOhm) . The brush is moved linearly across the screen, remains on the right for a certain time, then is moved back to the left.*







E03

They were young together

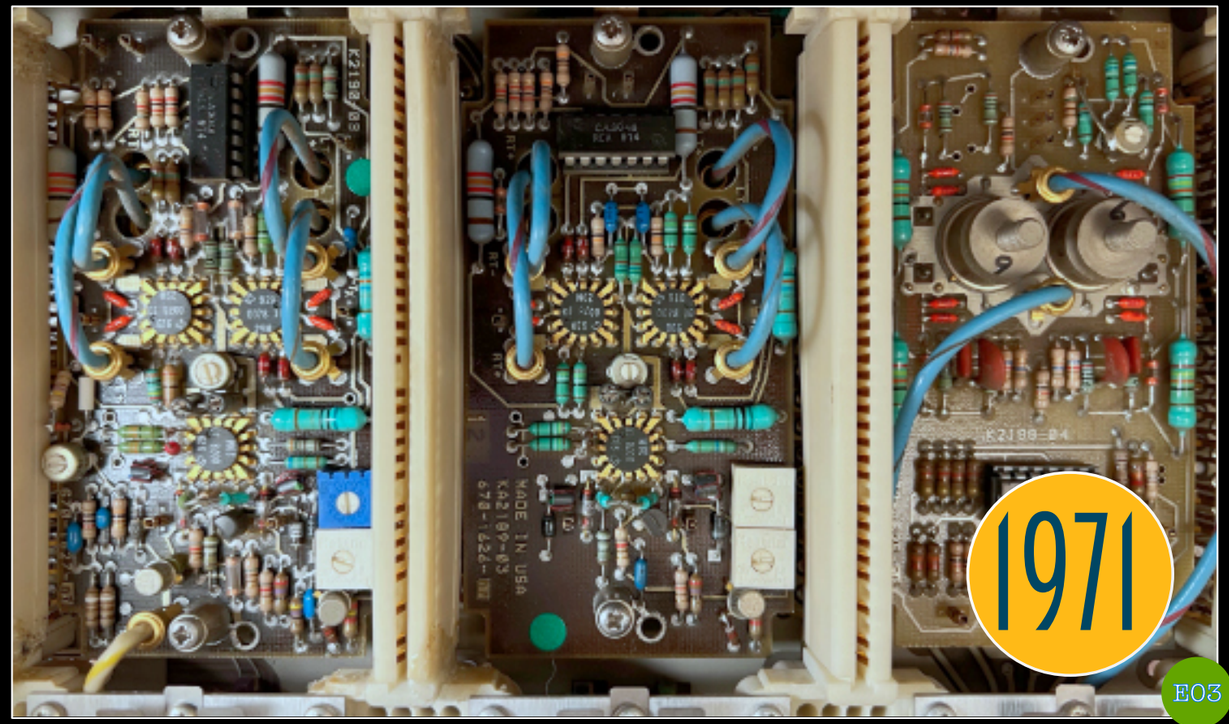
Here in the photo, you can see the first computer that I used, a Digital Equipment PDP-8/M. Not "a similar one", but exactly that one. It belonged to a Vickers-Medical automatic blood analysis system, that my father, as a director of a public health institute, decided to acquire in 1973. When it was dismantled, many years later, I surreptitiously got for me the two its PDP-8 and a Teletype. For the second time in my life, someone told me "sorry boy, we must officially destroy them". But one of the two PDP-8 was not officially listed, so they eventually allowed me to keep it, and it is still with me.

7904, 500 MHz bandwidth record man

The 500 MHz 7904, represents the evolution of the 1969 7704 and has four bays that can accept two 7000-Series vertical plug-ins and two horizontal plug-ins. It was introduced in late 1971 and was among the tops instrument, as expensive as a small apartment. Later, it was surpassed in price by the 1974 dual-beam 7844 and in bandwidth by the 1978 1GHz 7104.

Note: the photo on the left is a real fake, because... this 7904 works only thanks to the photo editing (as confirmed by the turned off lights on the panel). This unit is indeed only at the beginning of the restoration and lacks a lot of important parts, like, e.g., the power supply, the HV supply, the readout board etc. Thanks to eBay, I hope I can bring also this unit back into service.

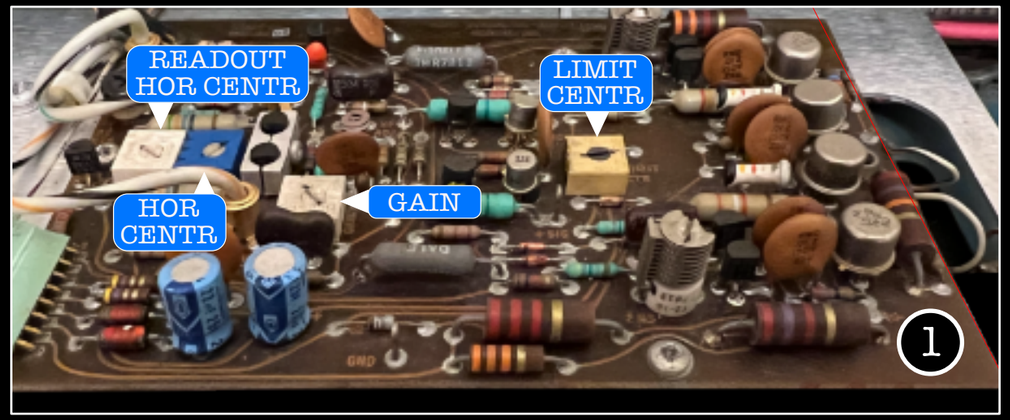
In the photo below: if you were a plug-in, you could see this panorama when entering your bay. The beautiful gold plated Tektronix M084 (155-0078) is a broadband vertical amplifier monolithic integrated circuit in a "minipac" package. Its inputs and outputs are differential.

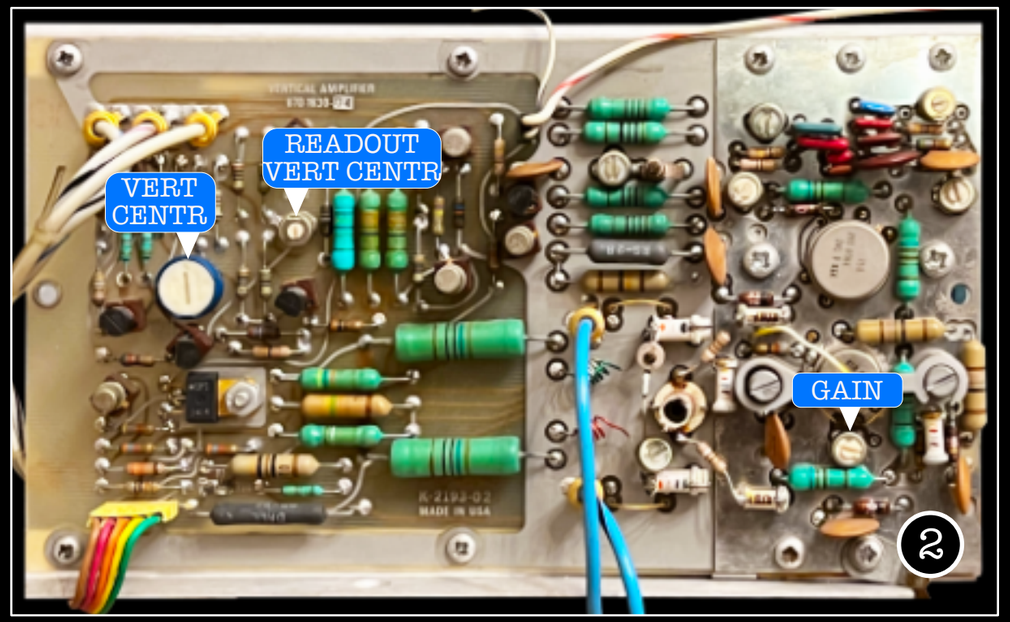


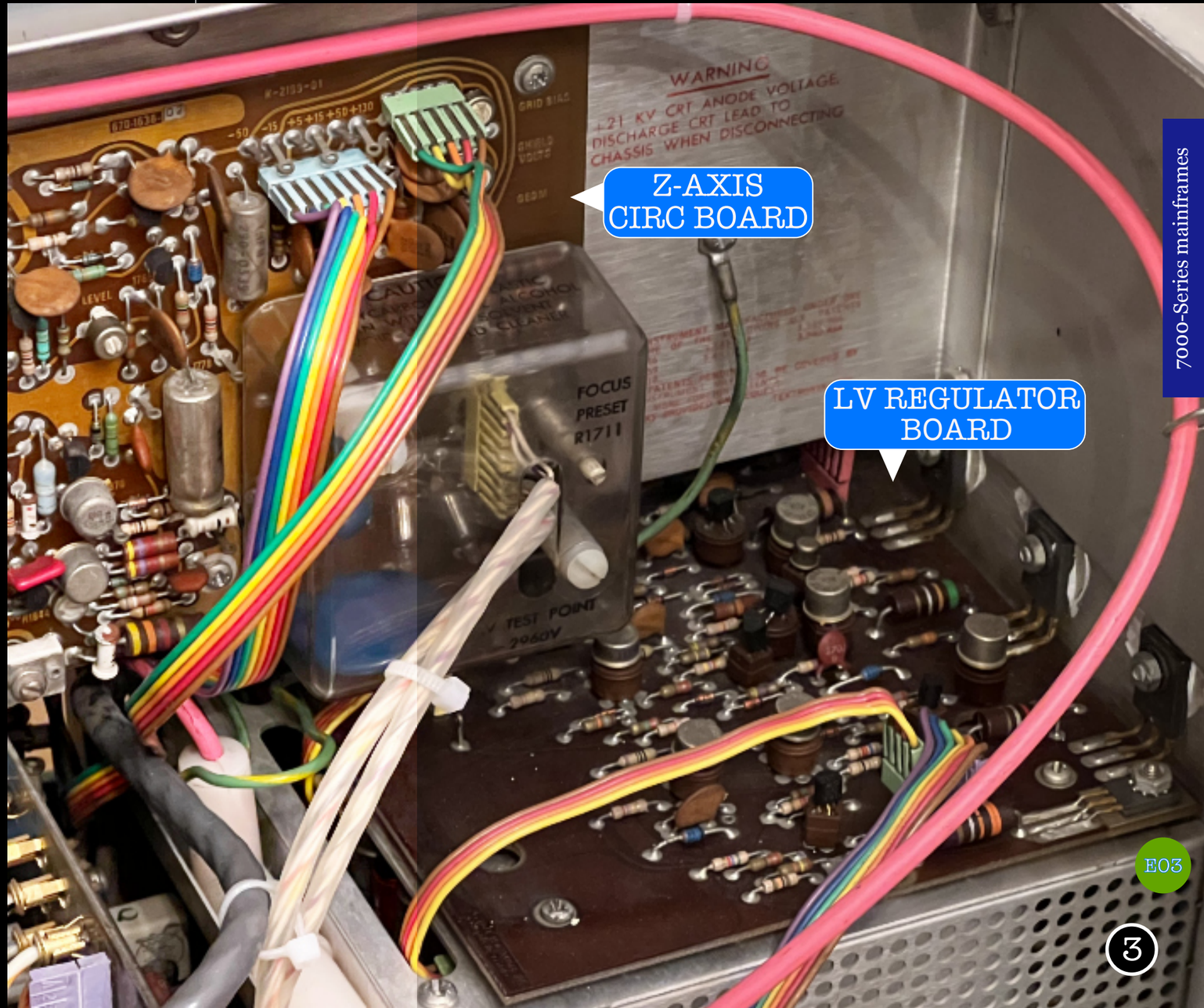
7904

In these photos, I added some labels that can be useful, not for the regular calibration, but for some retouch that could be necessary in the normal use.

❶ The horizontal amplifier.
❷ The vertical amplifier.
❸ The rear part of the 7904, with the Low Voltage regulator and the Z-axis amplifier.







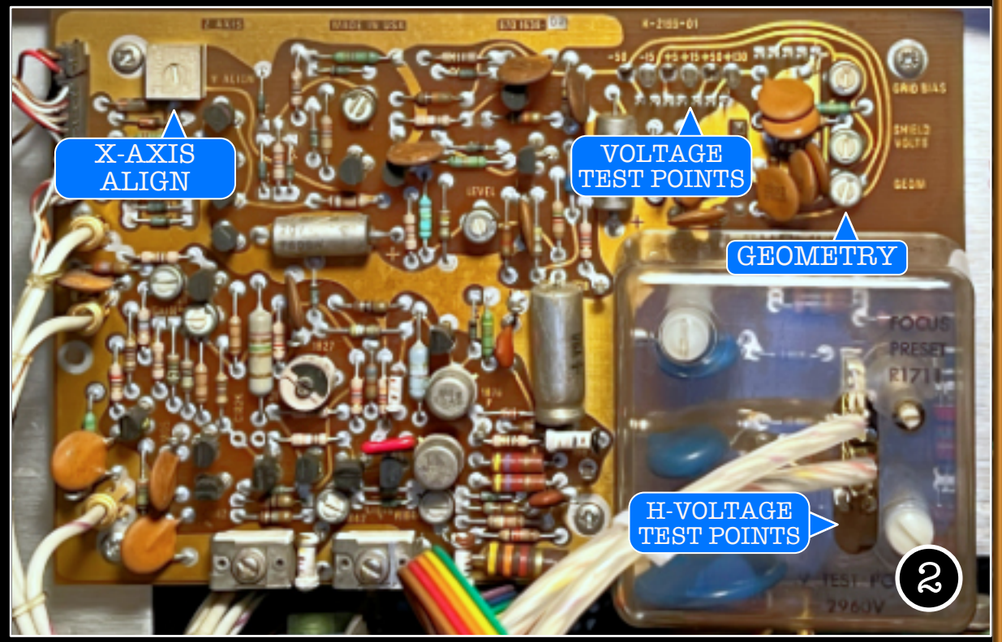
7904

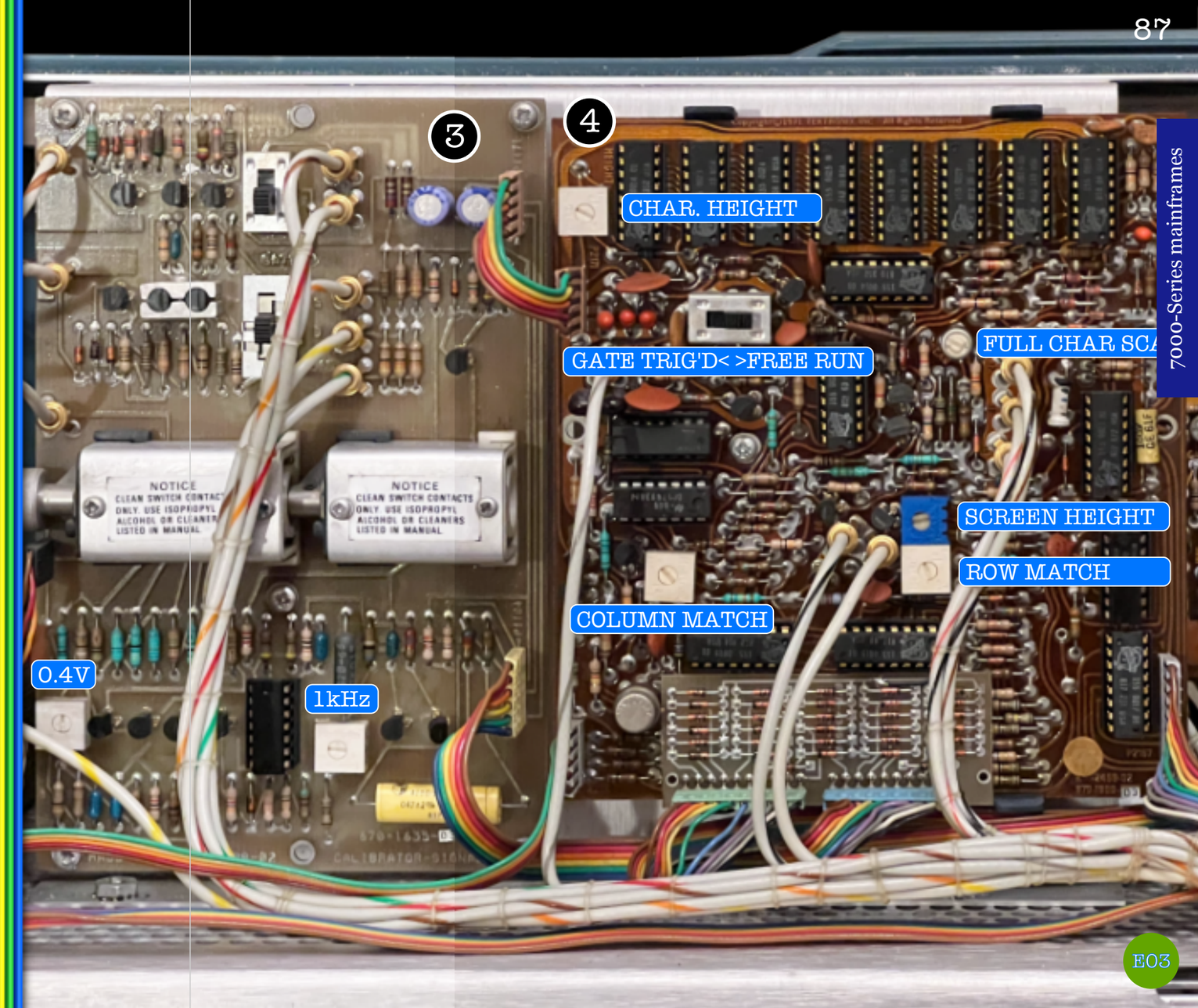
❶ OPTION 2: an optional X-Y delay compensation network was available for this instrument. This network provides close delay matching between the vertical and horizontal deflection systems up to one megahertz for use in X-Y applications which require precise phase measurement. The switches provide the possibility to use or not the compensation for both channels. For minimum distortion, when not necessary, the compensation should be kept disabled, setting the relative switch down.

❷ The Z-axis amplifier.

❸ The 7904 calibrator produces a far better signal than 7603. It can be adjusted with the labeled trimmers.

❹ The readout board. In my experience, that is the one that more often might require small readjustments.





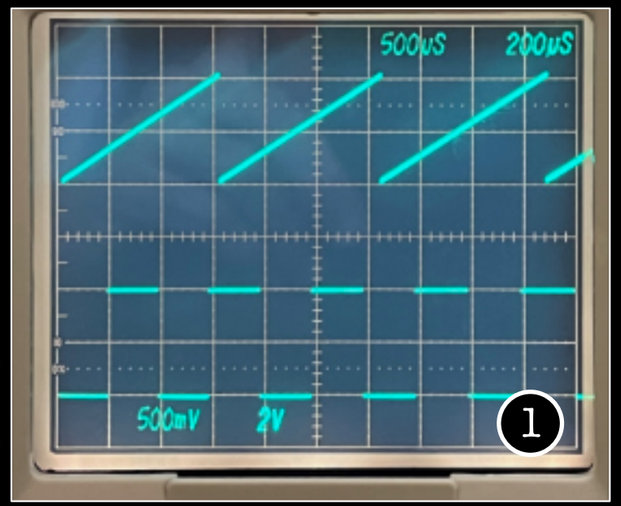
7904, what can I do?

So the new 7504 and 7704 offer 4 bays for plug-ins. What can we do with so many of them? The manual lists a lot of different modes, such as (I am talking about 7904 that I own; 7704 is not very different):

- ***single-trace**: single-trace vertical unit against one time-base unit;*
- ***dual-trace**: two single-trace vertical units against one time-base unit;*
- ***dual-sweep**: display of a signal at two different Time/Div (two trace on CRT);*
- ***dual trace-dual sweep**: display of two signals at two different Time/Div (four traces on CRT);*
- ***independent-pairs**: dual-trace, dual sweep display where the left vertical unit is displayed only at the sweep rate of the B time-base unit and the right vertical unit is displayed only at the sweep rate of the A time-base unit;*
- ***delayed sweep-single trace**: delayed-sweep display of a single-trace vertical unit;*
- ***delayed sweep-dual trace**: delayed-sweep display of two single-trace vertical units (four traces on CRT);*
- ***X-Y display**: one signal versus another rather than against time.*

*Some of them are rather obvious, but others less. Very interesting is the **independent-pairs**: it's wonderful to be able to display two asynchronous signals, each with its own time base. Note that in this case there are two triggers, each per trace (or couple of traces). So, if you want to measure phase differences, you need to invent something smarter.*

Interesting is also the possibility to use a vertical plug-in in the horizontal compartments and vice versa. If you put a horizontal time base (es. 7B53A) in the vertical compartment, you can use the "raster mode display", that shows a long trace that, as for written text, go to the next line when it



❶ Two traces on two independent time bases. Very helpful in this case the readout.

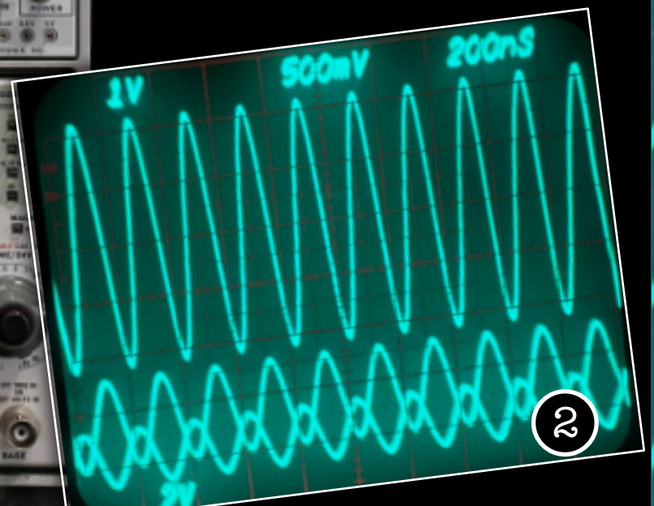
❷ Something wrong in this photo? Actually, it is not common to see an oscilloscope with three time bases, but the Tektronix designers were so smart that allowed to use vertical plug-ins in the horizontal compartments and vice versa for a raster display (see text).

reaches the end of the screen. How can it be done? Its very simple: it is sufficient to press the ADD button in the vertical mode switches and to connect the 7B53A external trigger input to the +GATE output of the scope. The sawtooth from this third time base, will move the trace to a new line as desired, adjusting properly the TIME/DIV switch on both the real and the auxiliary time bases. In a similar way, you can use a vertical plug-in in the horizontal compartment, to use the X-Y mode.

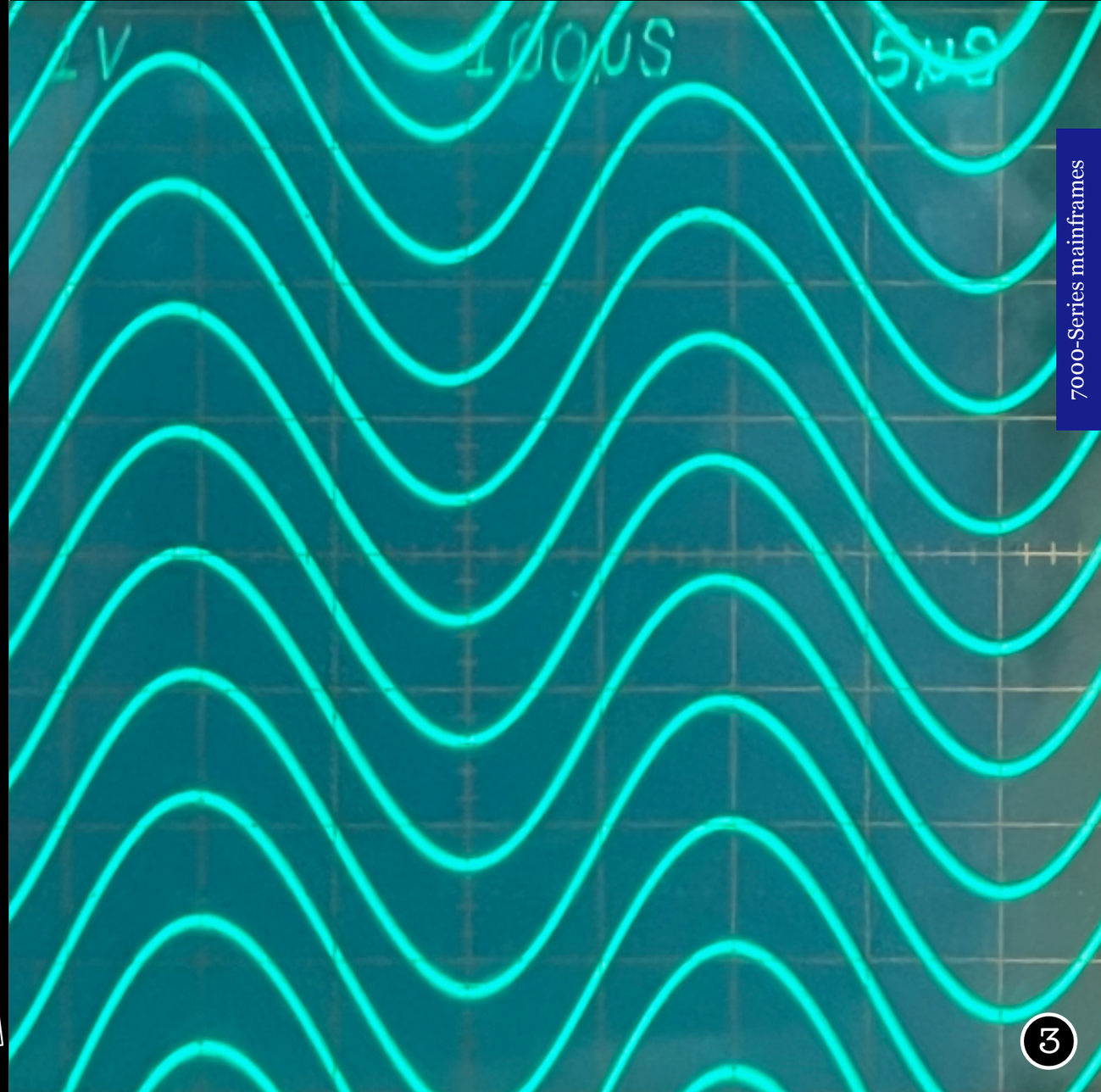
This interchangeability of plug-ins does not work only with 7904 but with all the 7000-Series models. Here on ❶, you can see a short pulse on a trace 108 cm long (9 traces long 12 cm each).

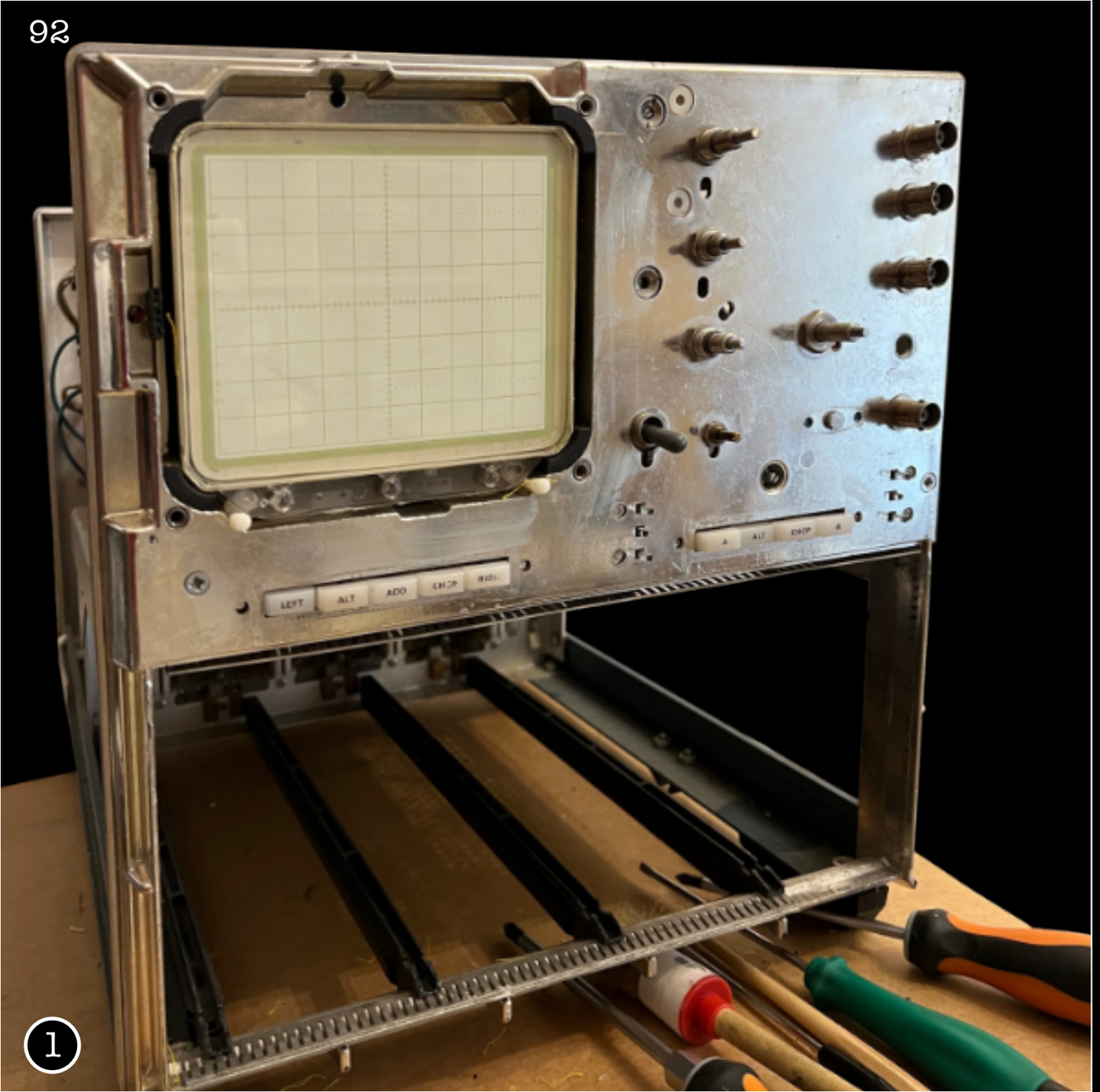
According Tektronix, combining the raster mode with the Z-axis modulation and properly setting the speeds, you can provide a television-type display, but I have not tried this.

I am not sure of what use all that might have, but surely it's very amusing to produce wonderful drawings on the beautiful Tektronix CRTs, in my opinion not matched by any modern TFT display...



❶ A 7603 with a 7B53A in the vertical compartment.
❷ A funny drawing stored in a 7623A storage CRT.
❸ Wonderful calligraphy of a 7603 oscilloscope. Note the presence of the optional blue optical filter (normally 7603 are green).





1

Story of a missed restoration

In the previous page, I told you that my 7904 was going to be restored, but it lacked all the power supply section. The 7904 parts that I have are in very good state indeed, so I bought on eBay another 7904, which was declared as "spare parts only", and not powering up. If it does not power-up, I thought, the problem is probably in the power supply; and then I thoroughly studied in advance the manuals and the Tektronix document "Servicing the 7904 high-efficiency power supply", finding the circuit extremely difficult and remaining scared of it. Then, the worm of doubt began to take hold of me: I can fix almost any passive or any transistor, but there is a threatening 155-0067-02 integrated circuit inside. And if... it was faulty? With pain, I discovered that it is very rare, and that you can consider yourself lucky if you find it at 100$.

So, now that the new 7904 just arrived, I am trembling while preparing to switch it up, scared for the possible holy smoke... OK, 1, 2, 3 ...go! Uhmmm, no smoke... no burst-mode click sound, as described in the article as a possible failure mode... Anyhow I don't want to insist... prudently, I switch it immediately off. Lets try with the multimeter to check the voltage values. I switch it on for just one moment... uhmmm... -50V? But it is OK! Now let's check the 130V. Also this it's ok. So, switching on and off, I am able to verify that all the voltages are as prescribed. I leave the 7904 on. Still no smoke. So might I dare something further (continued on next page).

2

❶ My second 7904 during the clean up. ❷ Dust everywhere inside it.

(continued from previous page)

Long breaths to calm myself down. And if I try to put a plug-in into? I take my worst 7B53A and switch the scope on again. Incredible, the trace gets on the screen! To keep it short: everything is OK, the new 7904 was not faulty!

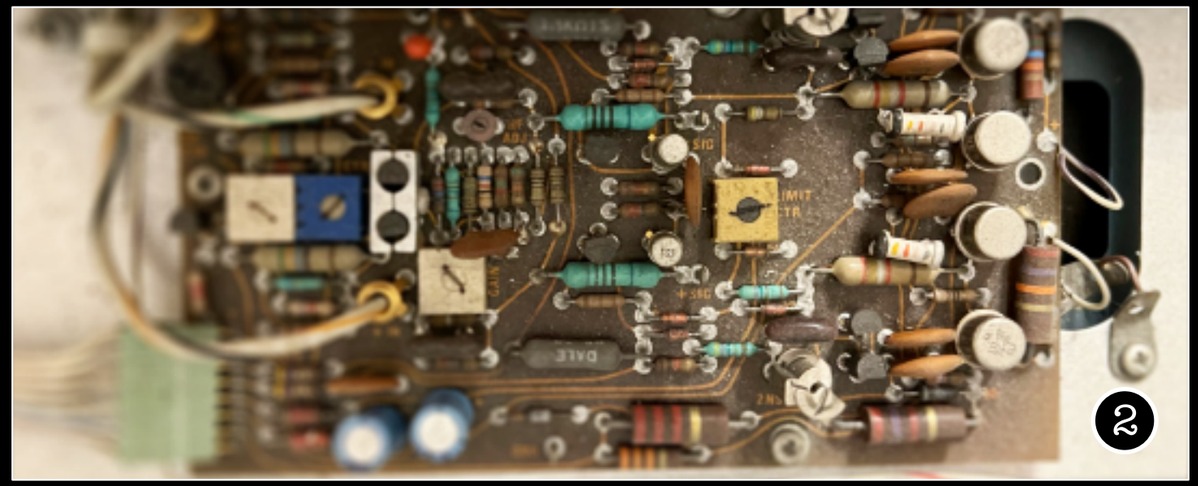
Its general conditions are somewhat worse than my first 7904, with plenty of dust inside. I believe that each of us has available just a limited number of miracles, and, after got the first, I don't want to abuse. So I decide not to pass the new parts to the old 7904 but, instead, to restore the second, with a moderate and delicate cleaning, to avoid any possible problem. In this way, I think, I will also respect more their originality.

After hours, when finished the clean-up, I power it on and... noooo! A terrible sound gets out from the CRT area. Panic. Surely that was my last miracle, I did something wrong. After a lot of checks, I understand that the HV is discharging to ground and the metal CRT screen acts as a trumpet. Perhaps I let drop some water into a critical area? I dry everything with an hairdryer and... the second miracle happens, it works again!

So, now I am the proud owner of a beautiful 7904. But what can I do with the first one? I have an idea: perhaps I should find a broken 7904, get from it the missing parts, and....

❶ Eventually! This is not a fake, this 7904 is really alive!
❷ Dust everywhere, but I proceed only with a slow and delicate cleaning, to avoid further problems.

1



2

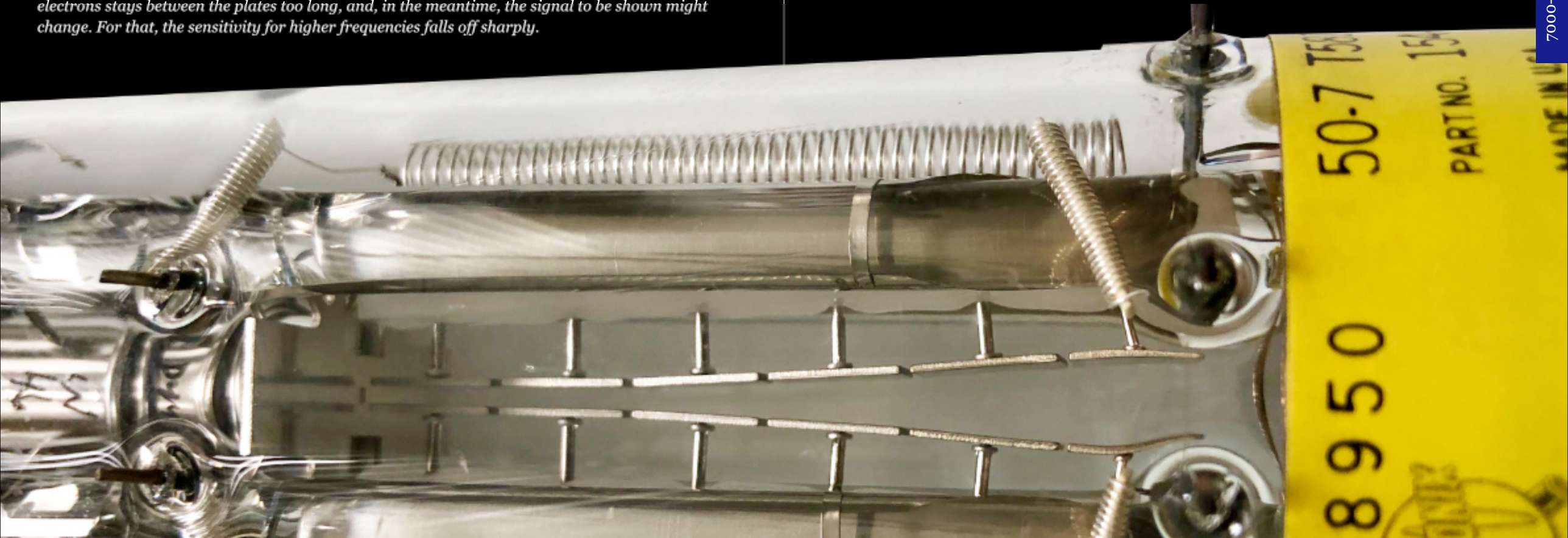
Distributed plates

Running after electrons

The 7904, like many other Tektronix oscilloscopes, used a CRT with distributed vertical plates. In conventional CRTs, a trade/off exists between acceleration voltage, deflection sensitivity and frequency response. As signal frequency increases, the acceleration voltage needs to be increased as well, in order to achieve sufficient beam brightness. This in turn reduces deflection sensitivity. To increase sensitivity again, the deflection plates need to be made longer. But, in this way, the electrons stays between the plates too long, and, in the meantime, the signal to be shown might change. For that, the sensitivity for higher frequencies falls off sharply.

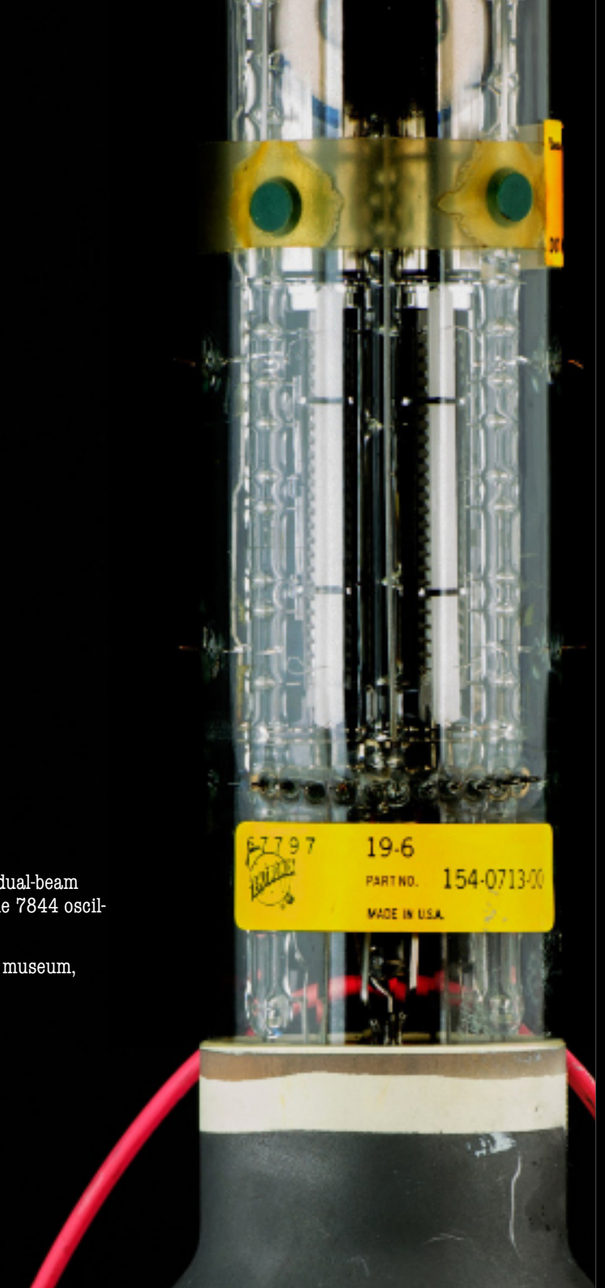
One solution to this problem is to segment the deflection plates into multiple pairs, each driven by a signal delayed just long enough to match the speed of the electrons passing trough the segmented structure. This is achieved through a delay line, typically a lumped-constant line built into the tube, where coils are placed between the plate segments, and the plate segments form constant capacitances.

Typically, only the vertical deflection plates are distributed. An exception is the 7104 due to the high horizontal system bandwidth required (350 MHz).



OS-245(P)/U
a military 7603

When you see it for the first time, you think: this is a normal 7603. But not: it is the 7603 military version, said OS-245(P)/U or 7603N11. It is declared "ruggedized" and fulfills many extra military specs. May be that also the material is different, because this unit is the best conserved of all my Teks, with no signs of corrosion at all. It had also different colors: dark grey instead of the classical Tek blue.

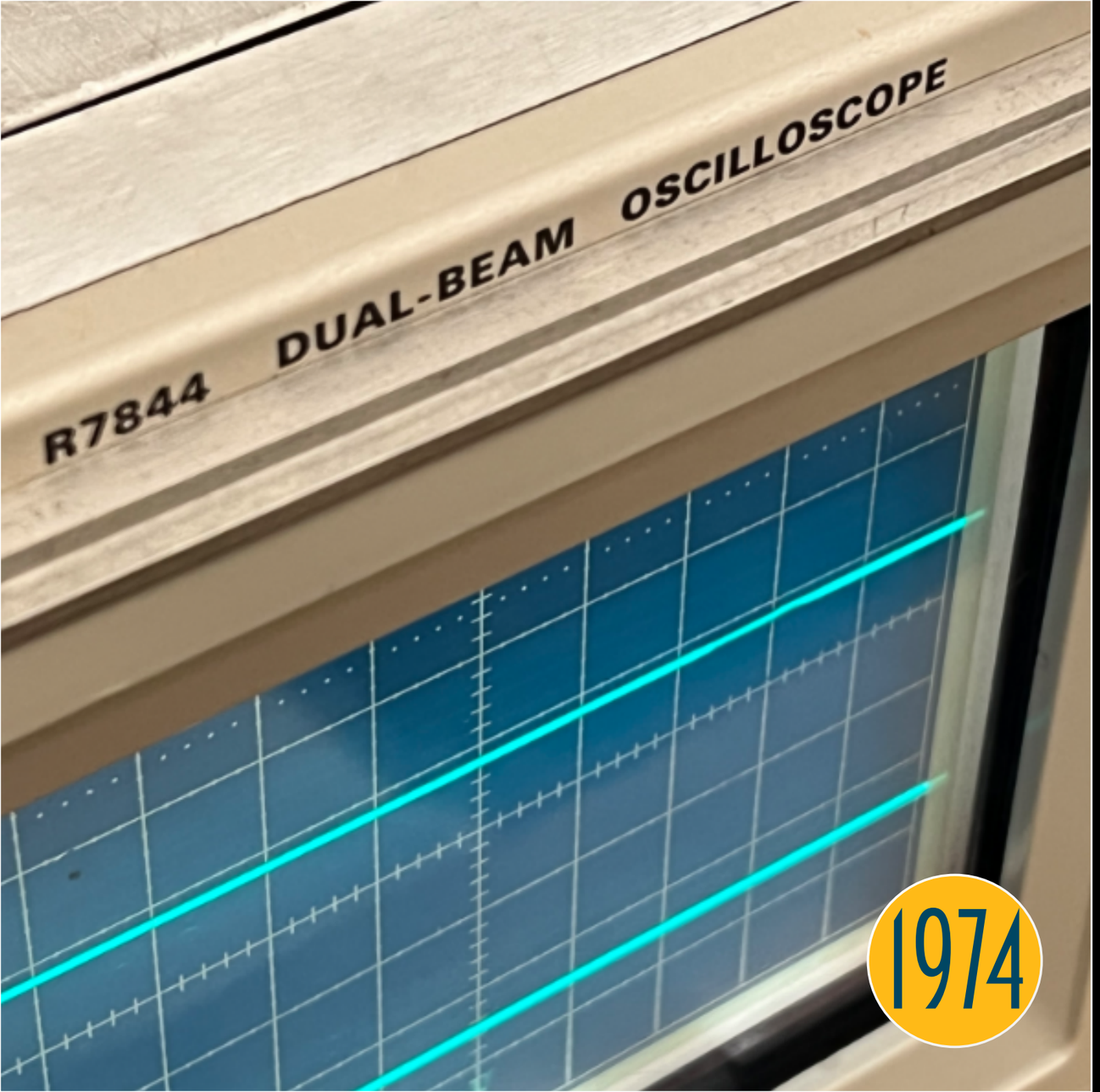


The awesome Tektronix dual-beam CRT 154-0713 used in the 7844 oscilloscope

(courtesy of VintageTEK museum, https://vintagetek.org)

Dual-beam mainframes

The top of technology in non-storage mainframes



R7844 dual-beam

Besides the mythical 7854, the 7844 is more complex than all other 7000 analog mainframes, because vertical and horizontal amplifiers, as well as the Z axis control boards and the delay lines exist twice, and there are extra switching logic boards. In consequence of that, the 7844 was one of the most expensive oscilloscopes in the 7000-Series.

Why the 7844?

When we need to examine fast, non-repetitive events, you needed a proper scope and a photo camera (or, as we will see, a storage scope).

In many applications, two transient events must be compared simultaneously. These application areas include stimulation and reaction events in such fields as medicine, biology, chemistry, engineering mechanics, to name just a few.

In this case, you could think to use a dual-trace oscilloscope, in the alternate or chopped mode. The former is for definition, not suitable for comparing two events, because one trace starts only after the completion of the other, and so not simultaneously. The latter (chopped) could not be practically used, for events that last less than about 100 µsec.

A possible solution could be using two different scopes, each of them with its camera, and then compare the individual shots with each other, but this is clearly not very practical. So the ideal solution (in the seventies) was a dual-beam oscilloscope. Dual-beam oscilloscopes can display two input signals separately and simultaneously; they are essentially two oscilloscopes in one. Each beam operates separately and independently of the other. When you capture two one-shot events using a dual-beam scope, comparing the two waveforms is no problem because they both appear on one photograph.

R7844 dual-beam

Why the R7844?

I present here the R7844, i.e. the rack mountable version of the 7844, because... I own this version. It is however very interesting, either because in this book we have no other rack version, either for its superb construction, which packs a lot of modules in a reduced volume (see later). To be noted, the good accessibility of the internal parts, in my opinion better than in the table-top version.

A great improvement over the past

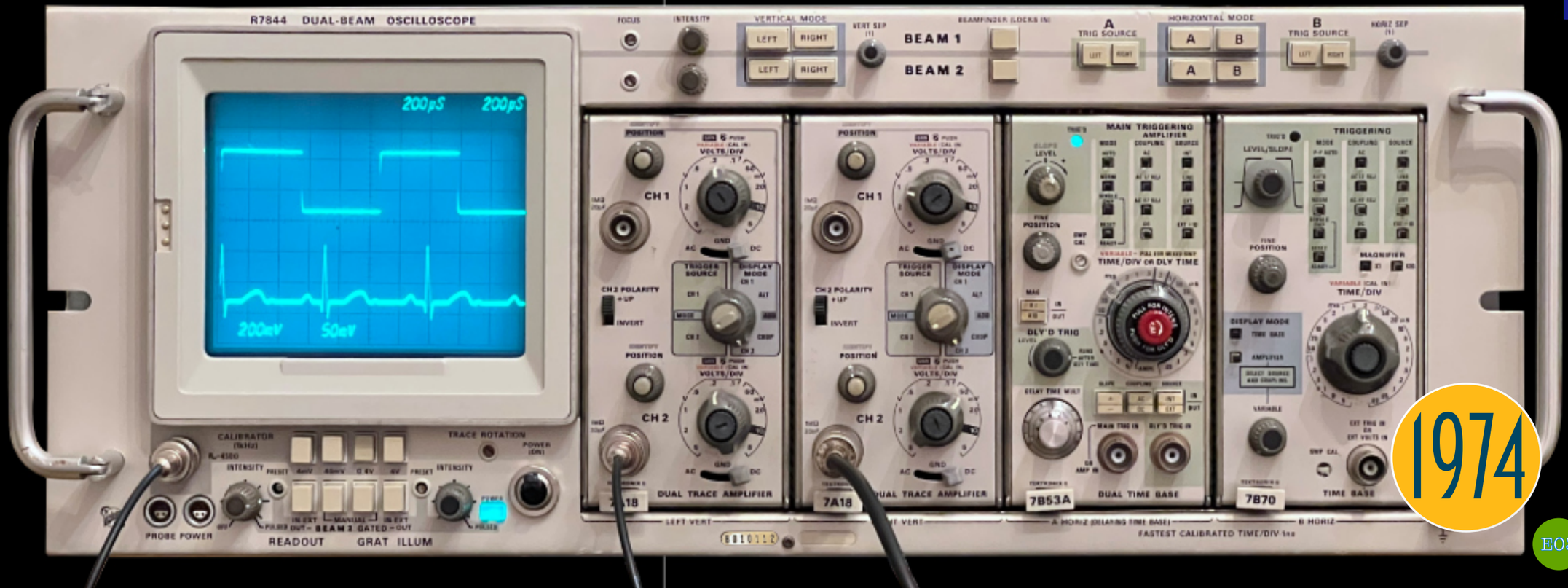
For the last nine years before the 7844, the fastest dual-beam oscilloscope available has been the Tektronix 556, a 50-MHz instrument. The 7844 has eight times the bandwidth, 400 MHz, that can be extended to 1 GHz using one or two 7A21N plug-ins with direct-access to the vertical deflection plates.

Volumes

A 7844 is very similar in performance to two 500-MHz 7904 scopes placed in one cabinet and made to share the same CRT screen. The volume of the 7844 is, however, the same as that of one 7904. In the "R" version (rack mounted), the volume has been further drastically reduced: the tabletop version is 56,100 cubic centimeters big, that drop to 39,400 in R7844. All are four-hole mainframes. The front-panel height of the R7844 is only 7 inches, one-half that of the rack-mountable R556. You could put two R7844's where one R556 was used before. The 7844 weighs only 36 pounds, less than half that of the 556, and power required 235 watts, less than one-third that of the 556.

Both beams write full screen

In previous dual-beam CRTs, each beam had its own part of the screen, with only four centimeters overlap. In the 7844 the entire 8 x 10 centimeter screen is shared by both beams, giving twice as much overlap area.



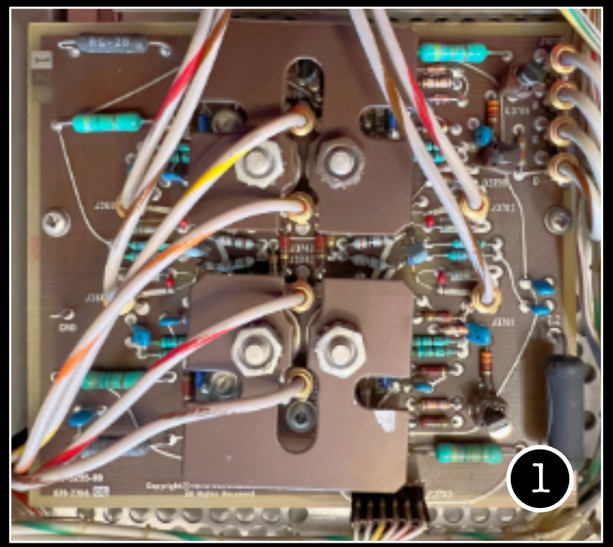
R7844 dual-beam

Designed for the camera

The 7844 was likely to be used with a camera, so had many special features not found on commo oscilloscopes, such as built-in film-fogging option (see below), pulsed illumination of the graticule pulsed readout etc.

Full dual-beam sometimes essential

Although two one-shot events are usually displayed using the same sweep speed, with both sweeps starting at the same instant, you sometimes need to compare two one-shot signals that don't occur simultaneously. A full dual-beam scope is usually called for, in this application. Two sweep generators are needed, one that sweeps one beam, and another that sweeps the second beam a little later. The 7844 provides maximum flexibility through four pushbuttons that permit sweeping either Beam 1 or Beam 2 from either time base unit without interchanging the units. Tektronix called this feature full ***horizontal crossover****.*



A similar feature is provided for the vertical channels. The signal from either channel may be displayed on either beam, without interchanging vertical plug-ins. Tektronix called this full ***vertical crossover****. It was performed by the vertical crossover board shown here on the left. You could buy the 7844 without it, saving 400$ (again a negative option). One of the advantages of vertical crossover is the ability to display the same signal on both beams using only one probe. This eliminates loading the circuit with a second probe. A typical application is measuring both the rise time and duration of a wide, fast-rise pulse. Both sweeps are initiated simultaneously, but one is set to run much slower than the other*

❶ The Vertical Crossover board that allows to switch the incoming signals from the vertical amplifiers to each of the beams.

❷ This picture shows the internals of the R7844, the rack-mountable version of the 7844. Tektronix engineers did a great work packing all those modules, almost two times a 7904, in a volume near 30% smaller.

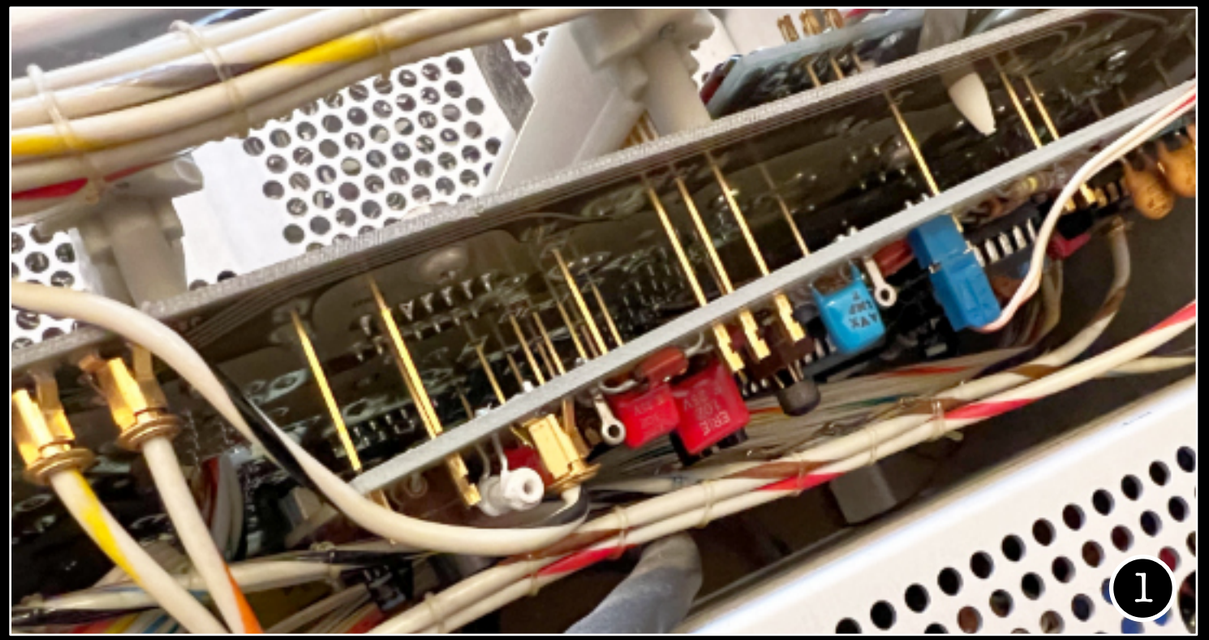
R7844 dual-beam

Reliability

Tektronix claimed that the reliability of the 7844 will be exceptionally good. The prospect of putting nearly twice as many parts into a 7844 as in a 7904 called for special attention to assuring instrument reliability. According to the available information, every conceivable reliability factor was scrutinized from the beginning of the project. Components with conservative voltage and power tolerance ratings were selected and air flow from the fan carefully controlled to limit temperature rise in all areas. Exhaustive reliability testing has taken place at all design stages.

From the user point of view, respect the 7904, the typical noise of a 1974 fan is a little annoying, but no surprise. The electronics is very well packed and the heat must be in some way dissipated.

❶ YOU MAGIC, R7844! When the R7844 arrived home, I started checking it rather thoroughly, and found minor faults and a broken transistor that blocked the time base A trigger. When I was convinced that there were no more problems, I decided to complete the visual inspection, removing the bottom plate, where I got a surprise: the logic board, piggybacked on the main interface, was bent and partially extracted from its seat. Carefully, I reset the board at its place. But it seems me magic that the R7844 could yet operate despite this!



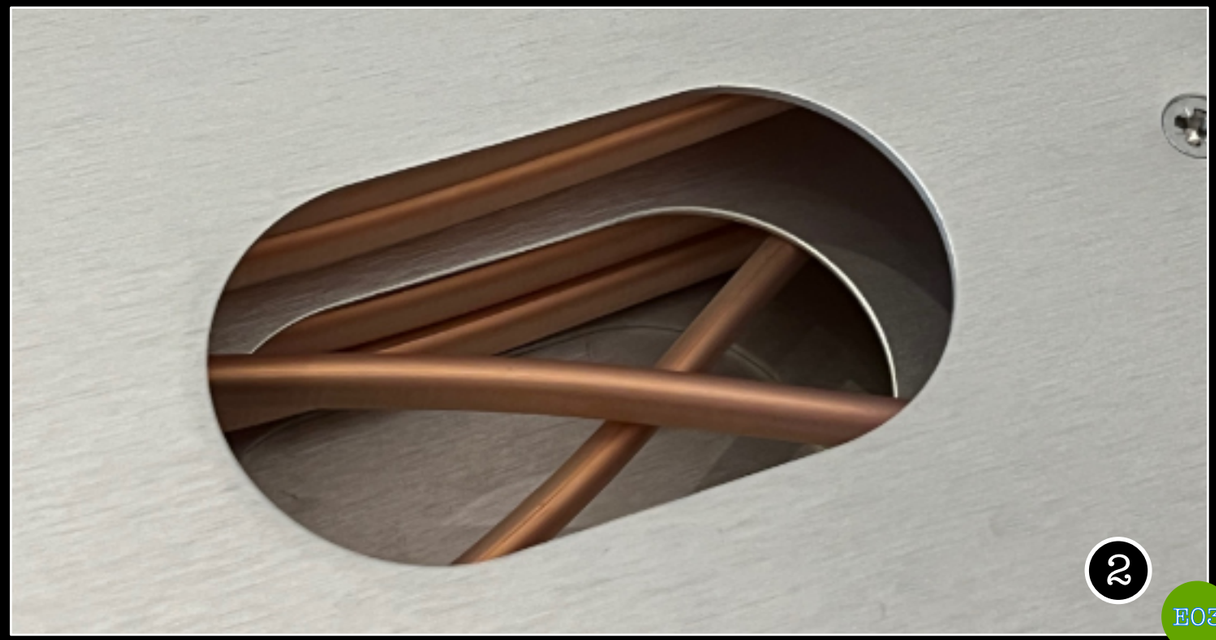
Some reflections

The 7844 was probably not a best-seller: it was very expensive and, in the normal use on repetitive signals, you have no relevant advantages over a normal dual-trace oscilloscope. Who bought a 7844, surely purchased also a Tektronix/Polaroid photo camera. Due to that, the instrument purchase was not the end of the expenses; the Polaroid film was very expensive and the 7844 was going to eat lot of it.

Today Tek photo cameras are easy to find on eBay, but the film is no longer available or available at collector prices. Anyway, no one would pay to do a screenshot of what you can do for free with a modern DSO.

All that being said, the 7844 is today an ultra-wonderful instrument, a monument to electronics, that excites and makes happy any stupid collector like me.

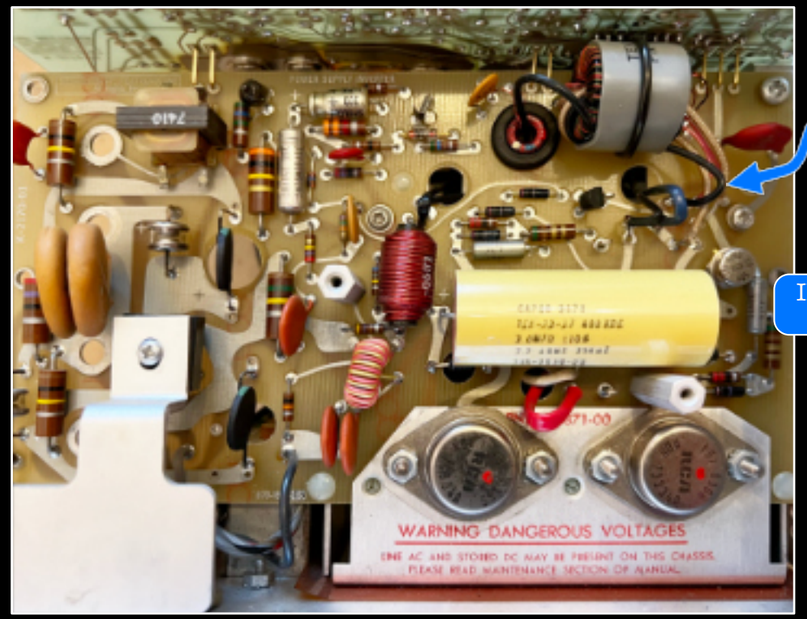
❷ A delay line is used to view the leading edge of the trigger event. The trigger and sweep circuitry need about 60 ns to start so there is no signal display during this time. A delay line placed in the vertical signal path after the trigger signal will result in the ability to display the trigger portion of the signal. Like many other parts, also the delay lines are duplicated in 7844.



High efficiency power supply

Generally speaking, I am not in favor of indiscriminate dismantling, on the contrary, I am always afraid of combining some troubles and causing damage to my beloved objects. In the past I was not so scary, but when you work in an industry you always take in account to break something and you have a more or less unlimited availability of spare parts. With old oscilloscopes, a damage could be almost impossible to fix, and you have to stop your work and wait weeks for the spare parts to arrive.

This is the reason because I have avoided to dismantle the "high efficiency power supply" that energized the great 7904, 7844, 7854 and probably the 7834, evolution of the one introduced with 7704, but using the 155-0067-02 custom (and rare) IC instead of discrete components.



So I stole a photo from the Internet to show you one of its boards speaking of the 7904.

But I was forced to overcome my fears to fix the ripple problem of my 7844 (see "Measuring ripple" in the restoration section).

RECTIFIER BOARD

INVERTER BOARD

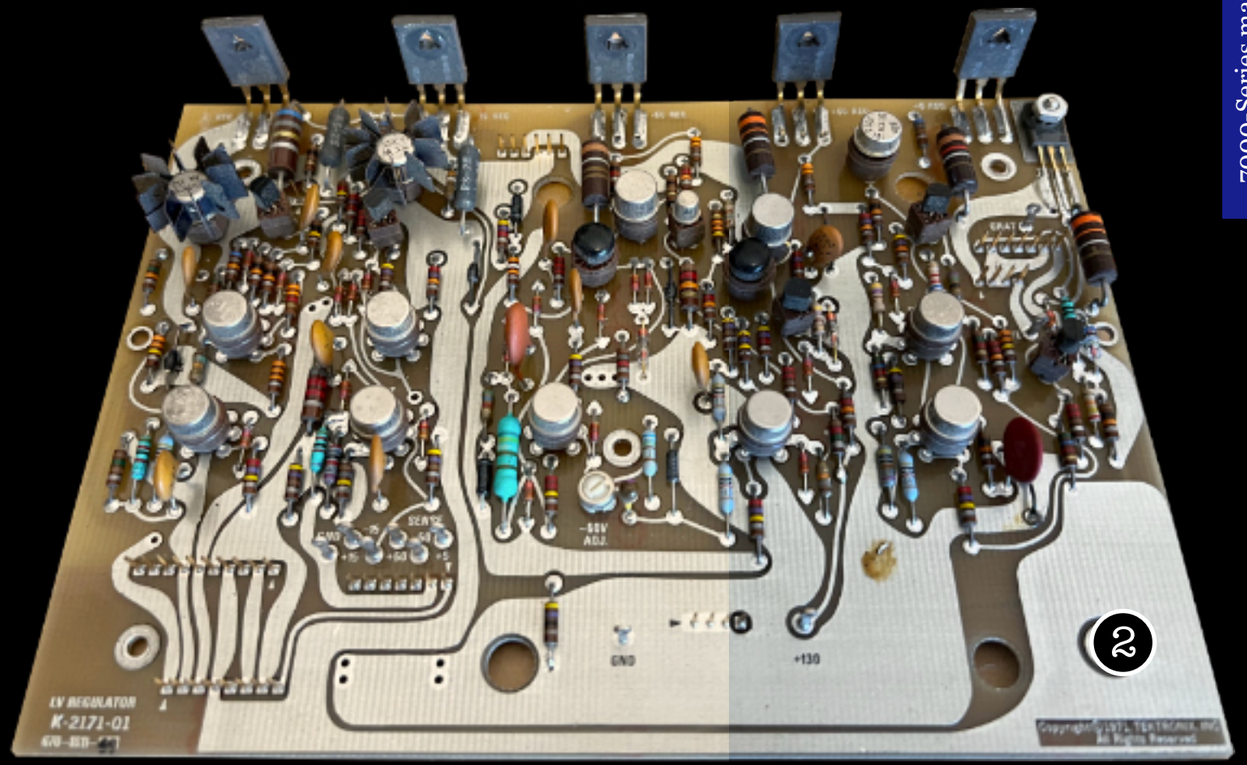
Having so dismantled the "high efficiency power supply" (I call it HEPS), I took the opportunity to get some photos of its internals, being the documentation of this old stuff one of the purposes of this book. By the way, without them the reassembly would have been much more difficult.

If you want to know about the work itself, it was for me psychologically difficult, for the large number of components to take apart and the possibility to make mistakes, with all those cables and connectors.

In the previous page, you can see the recapped rectifier board, purpose of my work. Note the radial capacitors used instead of the axial, because here are much easier to find in local shops and consequently also less expensive.

❶ The mains a.c. voltage is applied to a rectifier bridge and leveled by these two big capacitors. With 115V line, the voltage is doubled. In both cases (115 and 230V) the voltage to the inverter is almost the same (230V).

The HEPS uses an inverter directly powered by the mains, so the transformer is small and lightweight. Differently from 76x3 models, which use the traditional power supply, the HEPS integrates the high voltage section, that make things more complex. After the transformer, we find however normal rectifiers, capacitors and the linear regulator board, called Low Voltage board, similar in most parts to its 76x3 sister. Very practical the test point for every voltage, with a clear indication of their values. All in all, the HEPS is another demonstration of the 1970 Tektronix techical level.



❷ The Low Voltage board is very similar (even if completely different) from that of the 76x3 oscilloscopes, but without the big TO-3 transistors, replaced by a smaller case (TO-127 if I am not wrong). Here also, every transistor or IC has its socket, (even if hidden). Note the big 2W resistors: they are the way to measure and limit the maximum current and offer the possibility to measure the current consumption, measuring the voltage at their lead, using the Ohm law.

The death chamber

In the old electric locomotives there was a restricted area called "the death chamber", with all the high voltage components and connections. In the HEPS there is a restricted area for the CRT +24kV voltage generation, with its sealed transformer and the high voltage capacitors. Note the accurate construction, it is clear that they had experience in these things!

7844, not only hardcopy

Today, having a hardcopy of a modern DSO screen is straightforward. But with classic oscilloscopes, that was a huge problem, especially with non-repetitive signals. In this case, in fact, the point is not only the hardcopy, but also simply to be able to see the event, too fast for the human eye and immediately lost by normal non-storage CRT phosphors.

The first answer to this problem was a simple photo camera. Besides geometrical consideration, with non-repetitive signals, the question is: can a single sweep impress the film? It is obvious that part of the reply is in the film properties and part in the trace intensity/speed.

***Photographic writing speed** signifies the ability of a particular oscilloscope/camera system to provide a useful photographic record of a fast single-sweep trace. It is stated as an oscilloscope performance characteristic and is expressed in cm/μs or cm/ns. The writing speed parameter is designed to answer the question, "What is the speed of the fastest single-sweep trace the system can record?"*

All statements of writing speed must specify the measurement conditions, including the CRT phosphor and film used, and the definition of a readable trace image.

Tektronix designed and produced a lot of cameras, suitable to be used together with its oscilloscopes, like the C-50 depicted in the photo on the left.

In the case of 7844 oscilloscope, the catalog says:

> Minimum Photographic Writing Speed- 1.7 cm/ns using Polaroid type 47 film, C-51R and optional P11 phosphor. In typical applications, P31 phosphor has about ½ the writing speed as P11 phosphor.

My R7844 oscilloscope has, like most of the produced units, the P31 phosphor, so, its writing speed in the above conditions, is 0,85 cm/ns or 850 cm/μs.

Film fogging techniques

The catalog states also that:

> Writing speed can be increased by using the TEKTRONIX Writing Speed Enhancer or Polaroid type 410 film or both.

This Speed Enhancer is a device capable of raising the writing speed using the film fogging, a technique that implies applying a controlled exposure of the Polaroid film to a light source.In fact, at very low light levels, little change in Polaroid film density occurs over considerable variation in light intensity. This occurs because near the threshold of film sensitivity, exposure and the resulting film contrast is a non-linear relationship. Additional exposure to light can effectively increase the low-level sensitivity of the film and provide greater viewing contrast.

The picture shows the Tektronix Writing Speed Enhancer, a light diffuser mounted behind the lens in the camera that provides accurately controlled "film-fogging" illumination levels. The Writing Speed Enhancer allows variations of these fogging illumination levels for use with films with various ASA ratings.

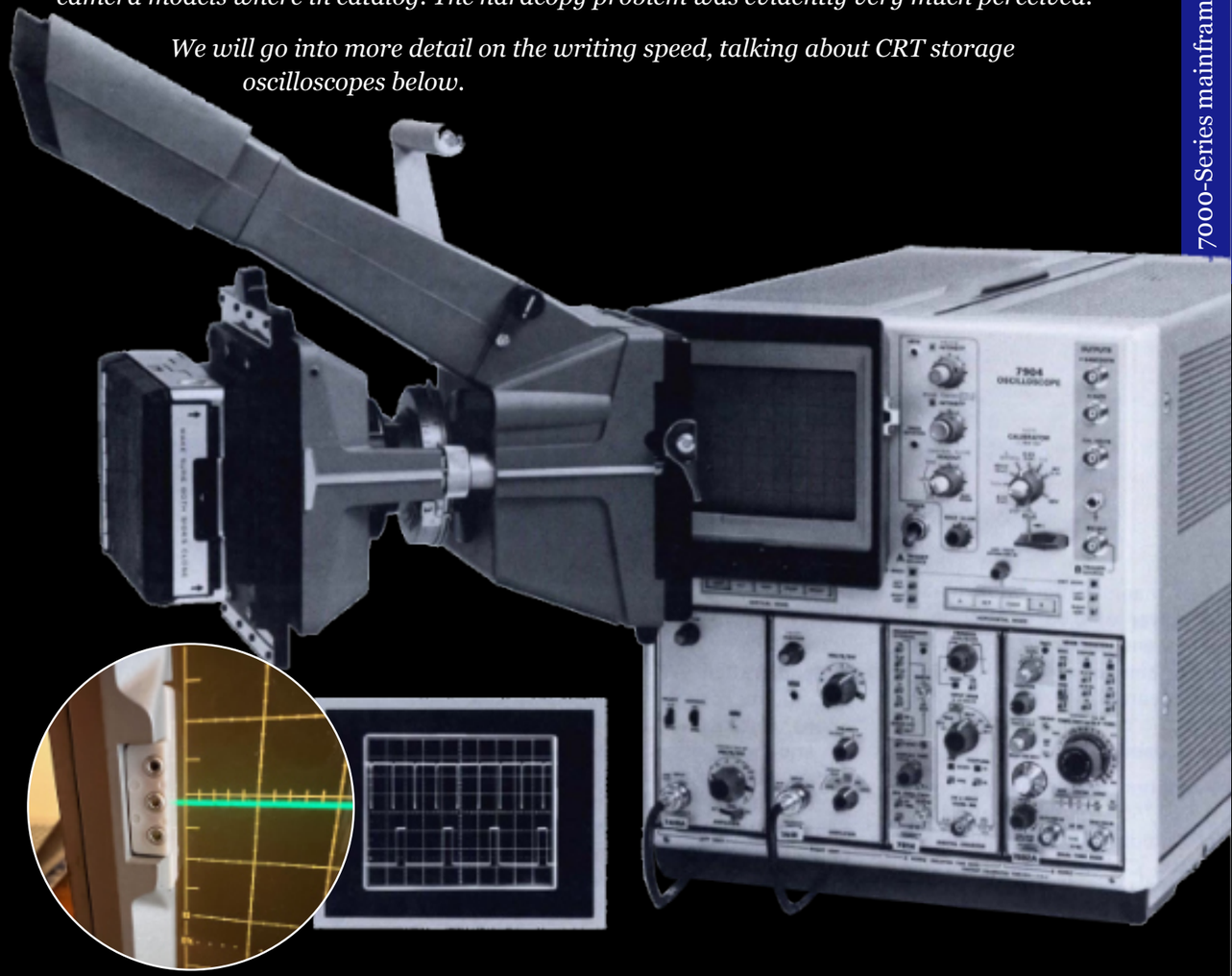
a

Some scopes, like the 7844, offered also special features for the phots. For example the pulsed graticule and readout illumination. They provides means of pulsing the graticule lights, or CRT READOUT, at a preset level, coincident with a single-shot event in one exposure. The graticule lights or CRT READOUT can be pulsed by the event, an external ground closure, or front-panel push button.

Tektronix offered a full line of oscilloscope cameras, all based on Polaroid film, so that the photos could be immediately developed and seen.

Every oscilloscope was provided with a special bezel to allow the photo camera mounting, complete with contacts for the electric control signals (see detail). In 1976, more than 10 photo camera models where in catalog. The hardcopy problem was evidently very much perceived.

We will go into more detail on the writing speed, talking about CRT storage oscilloscopes below.



The Tektronix 154.0723 storage CRT used in 7623A oscilloscope.

CRT storage mainframes

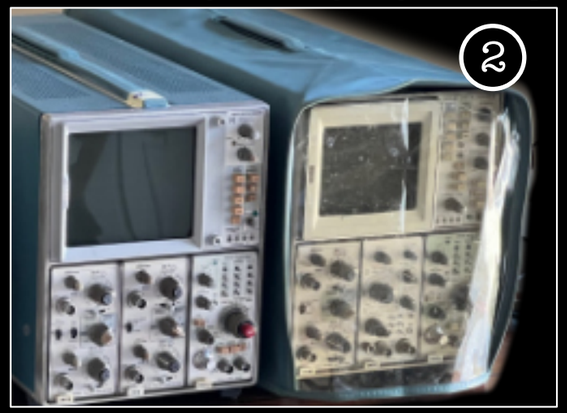
As we have seen talking about the 7844, capturing non-repetitive events was almost impossible in the seventies with conventional scopes, unless you used a photo camera, very expensive also for its hunger of Polaroid film. Storage CRT scopes promised the solution of this problem and would allow an unlimited number of shots, without the inconveniences and the price of the photograph.

7623A, camera no longer required

In my opinion, the Tektronix CRT storage technology is one of the most fascinating. Today all seems easy: any electronic device has a memory and everything can be "frozen". But in the seventies, as we have seen, catching non-repetitive events was really tough.

In the 7603 photo, I confessed that the display of the scope on the left was a fake: no probe connected, no display possible. But in this case, the photo on the right is not a fake: it is a real image stored in the CRT memory of my 7623A. This instrument has a very interesting story: it was acquired more than 40 years ago by some public institution, placed on a shelf and, almost surely, never used.

Its condition is mint: it was preserved also by the original Tektronix cover, which prevented the dust and the corrosion to enter the instrument. I consider to be lucky, owning this extraordinary unit.



❶ The dust covered, original Tektronix plastic cover that preserved the 7623A for more than 40 years. When I got it, it was even more dirty than that.

❷ and ❸ The cover is still today absolute top-quality: besides the age, it conserved all its original flexibility and, now that is clean, looks again like new.

1975

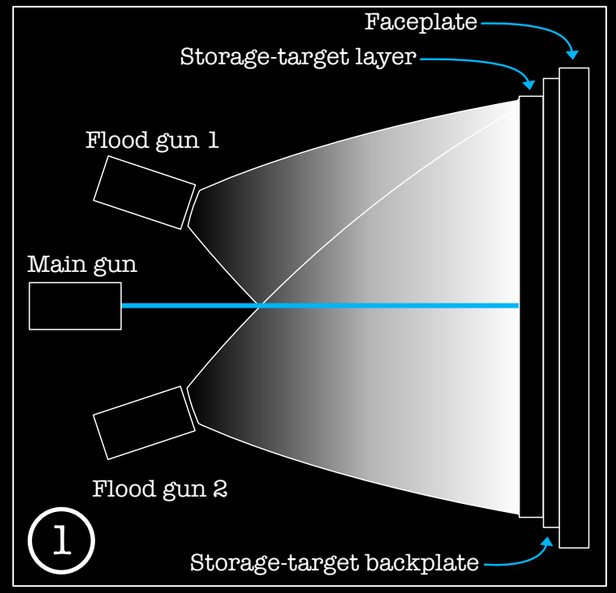
Analog storage CRTs

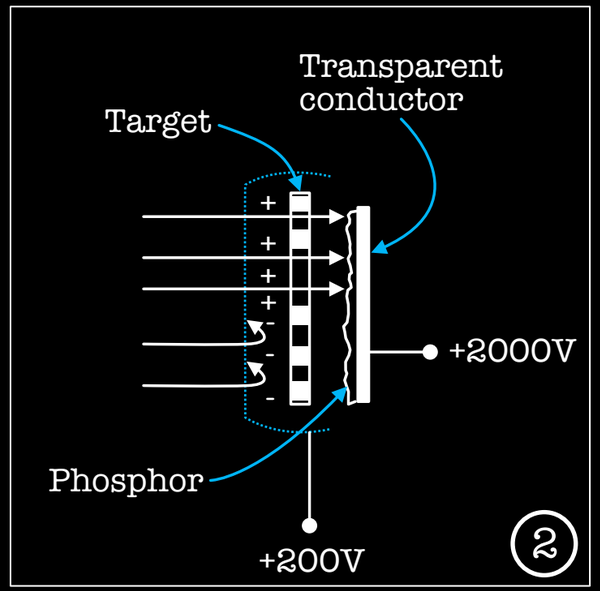
"The development of the laboratory oscilloscope has been marked by a handful of major breakthroughs. Of these, Tektronix probably can claim more than its share, no matter whose list you look at. And almost every list will include practical storage. The storage cathode-ray tube not only has added a new dimension to our oscilloscopes, the ability to retain a waveform display, but also has triggered our first product diversification, and the formation of a new division to produce information display and large screen monitors."

This was the beginning of the article "THE STORAGE STORY", probably from 1967, that tells the history of this big Tektronix success. You can find a lot of information, on the Internet, about that, but if you just want to have an idea of how analog storage works, just go on and read here a very minimal resume of it.

A storage CRT i's much like a conventional one, with some special features:

- *it has two electron guns instead of the usual single gun; the added one ("flood gun") can cover the entire phosphor screen with a slow stream of electrons;*
- *a phosphor layer that, unlike the phosphor on a standard CRT, is only semi-continuous, or porous;*
- *a conductive transparent faceplate, under the phosphor to collect secondary electrons (continuing on next pages).*





❶ General architecture of a storage CRT.

❷ The base mechanism of the storage. The positively charged areas allow flood electrons to pass and activate the phosphor, while the negative areas repulse electrons making the area dark on the screen

❸ The 1966 Tektronix 549 storage oscilloscope. A quantum leap in the electronics history.

1966

3

(continuing from previous pages) One gun writes like any CRT does: it bombards the phosphor screen with a focused electron beam, pushed at very high speed. The phosphor lights up; this dot of light, moving across at high speeds, appears as our familiar traces. The beam, as it writes, also does another thing: hitting with tremendous force, it knocks loose great numbers of secondary electrons. Thus, the written surface (where the waveform is), losing electrons, charges positive. Now the graph can be stored, using the flood electron guns, which emit a low-energy stream of electrons over the whole screen. They:

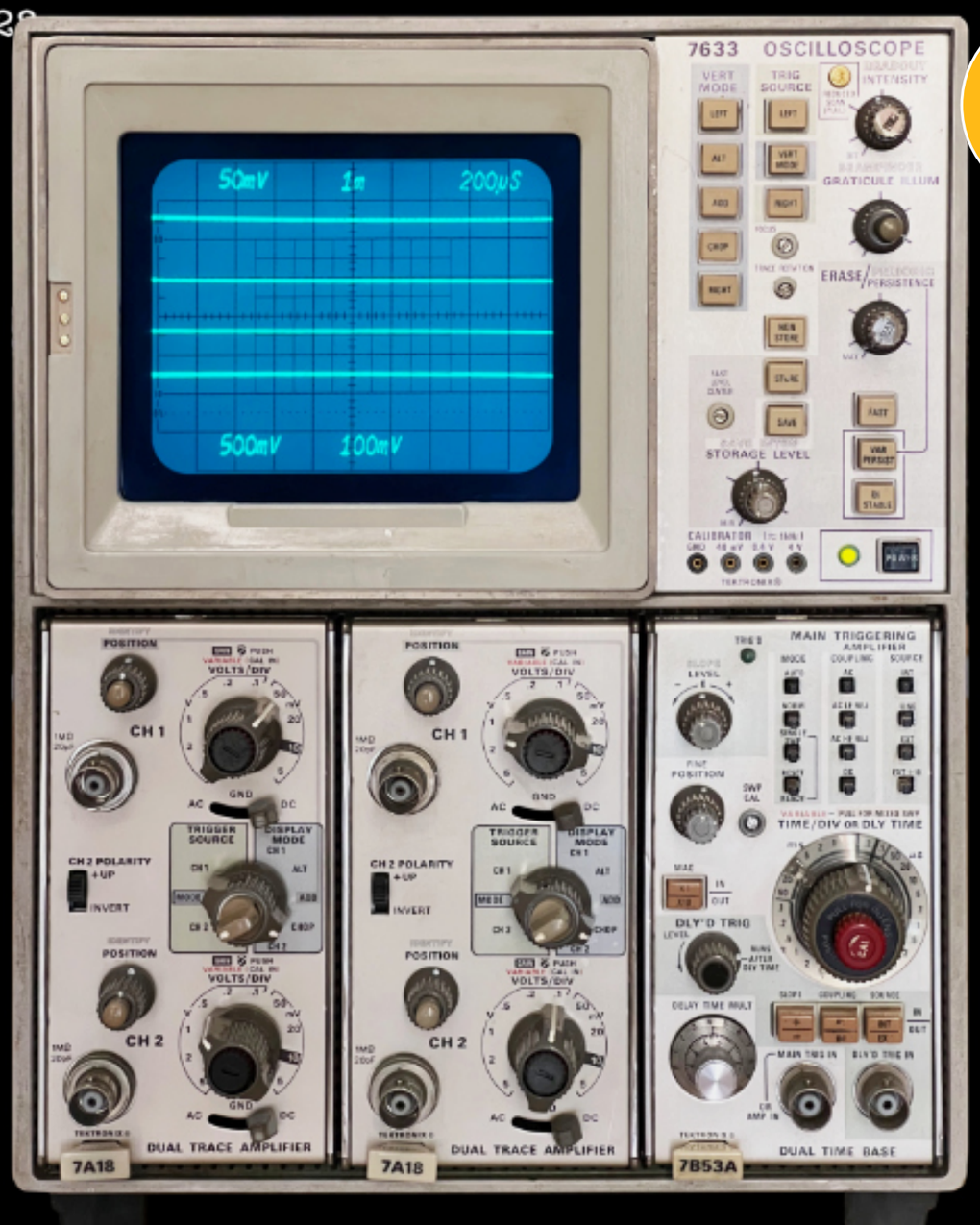
- *hit the unwritten areas too slowly to jar loose many electrons. These areas merely collect the electrons until they're driven negative, and can attract no more current.*
- *are attracted with considerable velocity by the invisible charged image, where the beam has written. They hit hard enough, not only to keep the phosphor bright, but also in a way that each entering primary electron knocks loose one secondary.*

Thus the written area neither gains nor loses electrons, and remains positive, able to keep attracting the flood current; thus it can store the bright trace as long as you need to.

You may compare the action of the primary electrons on the charged areas to the action of a strong stream of water falling from a height into a cup. It will never fill the cup, because its own force keeps splashing some water out. Another cup, held close to the faucet, would be filled by the same stream. This, then is the phenomenon of storage: the same flood current that holds the background dark also holds the written trace bright-and it will do so as long as you want it to.

Things are much more complicated in reality, and huge researches led to the practically usable storage oscilloscopes, that where helpful, if not necessary, for the evolution of human science, not only in electronics but in dozen of other fields.

In the photo: the 7623A storage control board. Its purpose is to produce the proper pulses to allow the storage CRT to perform its duty. Note the usage of the first 74-Series integrated circuits.



1974

On the right: the reduced scan, signaled by the yellow lamp on, was not a very elegant solution indeed and was perhaps accepted only because the CRT storage technology simply could not do much better

The time for switching to digital storage technologies was coming.

7633, 2,222 div/µs

In the previous edition I was a victim of the Tek's confusion between cm/µs and div/µs, and, worse, I forgot to consider the 7834/7934, confirming that I am not an historian, but only a guy trying to put together some information. Now I try again after having studied more...

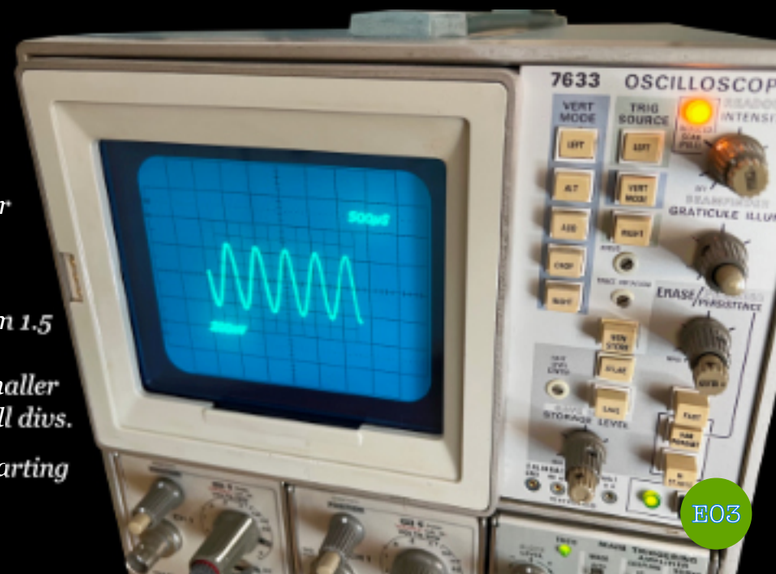
In a storage oscilloscope, it's easy to understand that a critical point is the capability of the CRT to register fast events. The writing speed is measured in cm/µs or div/µs, (the latter is more impressive being divs smaller than cms). In 1972, the entry level 7000-Series storage scope, the 7613, could reach only 4.5 cm/µs, while the 7623 was at 100, far below the photographic paper (up to 15,000 cm/µs).

In 1974, the 7633 was introduced, with exactly the same writing speed of the 7623, but with a tricky improvement: sensibly reducing the scan dimension, increasing the speed to 1,000 cm/µs. That artifice had another advantage: reducing the division size, the improvement in the writing speed was even more impressive: 2,222 div/µs. The 7633 was so capable to avoid, in many applications, the trouble of the photo camera to catch non-repetitive events, with comparable writing speed, becoming so a competitor of the camera itself.

This improvement is achieved by increasing the CRT cathode voltage from 1.5 kV in the full scan mode to 3 kV, which results in higher beam energy and a smaller spot size, and downgrading cms to small divs.

The storage technology was however starting to show its limits.

	7613	7623	7633	7633 red.scan	7623A	7623B
Year	1972	1972	1974		1975	1991
Fast var pers	5	100	150	2,222	150	Same as 7633
Fast bistable			50	400	50	
Var persist		0.5	0.5	3	0.5	
Bistable		0.03	0.03	0.2	0.03	



Top and sunset

Model	Year	div/µs	div/µs
7613	1972	4.13	5
7623	1972	100	111
7633	1974	135	150
7623A	1975	135	150
7623A reduced	1975	1,000	2,222
7834 reduced	1977	2,500	5,500
7934 reduced	1987	4,000	8,800

In 1975, the 7623A just introduced some improvements over the 7623.

The swan's song of the CRT storage technology were the 7834 and the 7934, both in the 7904 form factor:

- *the 7834, built from 1977 to 1986 offered 2,500 cm/µs (5,500 div/µs) in reduced scan mode;*
- *the 7934, built from 1987 to 1991 offered 4,000 cm/µs (8,800 div/µs) in reduced scan mode;*

I learnt that the 7934, that came out in 1987, late in the 7000-Series lifecycle, was not listed in the 1988 catalog, for not known reasons. It reappeared in the 1989 editions. Perhaps doubts that it could be too late for CRT storage, being already in catalog scopes such as 11401 and 11402 DSOs?

In 1991, Tektronix decided to drop all the CRT storage models, but the new 7923B, practically a renamed 7633, and the top gun 7934. Still alive, but briefly. The two had had their days, and the DSOs were the absolute winner over the CRT storage technology, now on sunset boulevard. This makes the 7633, in my eyes, one of the most significant pieces of my little collection.

◁7934 7834▷

Again the writing speed

*I wish to finish talking about the storage scopes, trying to better explaining to me the meaning of the **writing speed** parameter, that we already met talking about the 7844.*

*The writing speed does not coincide with the **sweep speed**, because in general the trace runs not only horizontal but also vertical. So, we have to consider the effective path that the electronic ray travels, painting the trace on the CRT. The writing speed coincides with the sweep speed only when the trace is perfectly horizontal. A perfectly vertical trace, instead, impossible in the reality, should require an infinite speed.*

For simplicity, consider a real case of a repetitive 40MHz sinusoidal signal (see the photo in this page, taken in repetitive non-store mode), but let's pretend that it was a non-repetitive event, using the single-sweep mode. In non-store mode, without a camera, you just see nothing, the event is too fast.

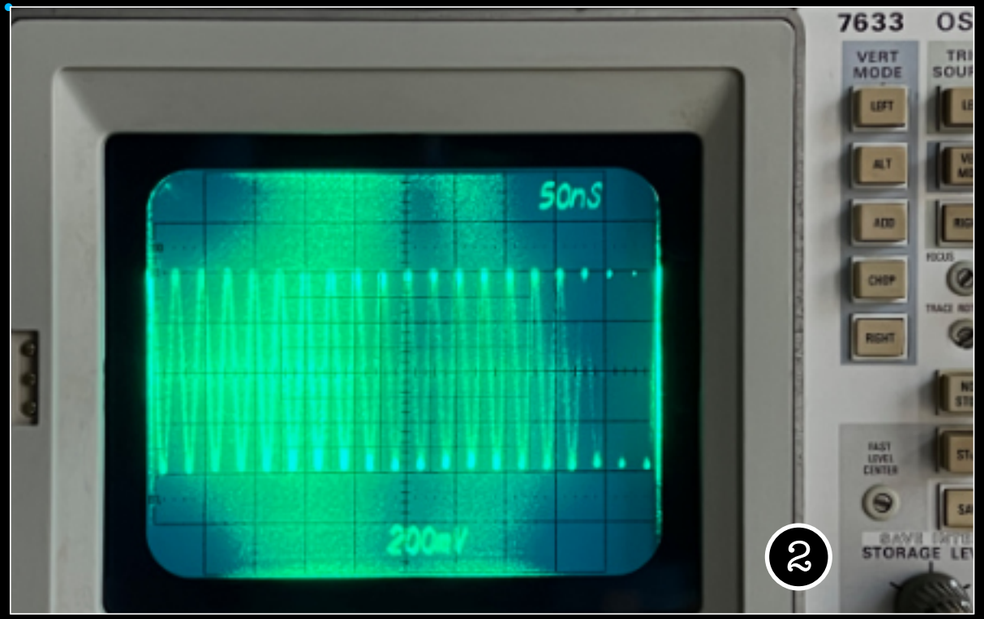
As you can see, each CRT horizontal division contains about 4 almost vertical segments, each long about 4 vertical divisions. For each horizontal division, the trace travels so for 4+4+4+4+1 = 17 divisions.

As shown by the readout system, the scan speed is, in this case, of 50ns/div. In 500 ns the trace travels for 170 divisions and the speed is thus 340 div/µs, far above the maximum store mode declared by Tektronix for the two oscilloscopes we are examining (respectively 100 div/µs for the 7623A and 150 div/µs for the 7633).

Now let's go to STORE, VAR PERSIST, FAST. The photos ❶ and ❷ compare

1

7623A



2

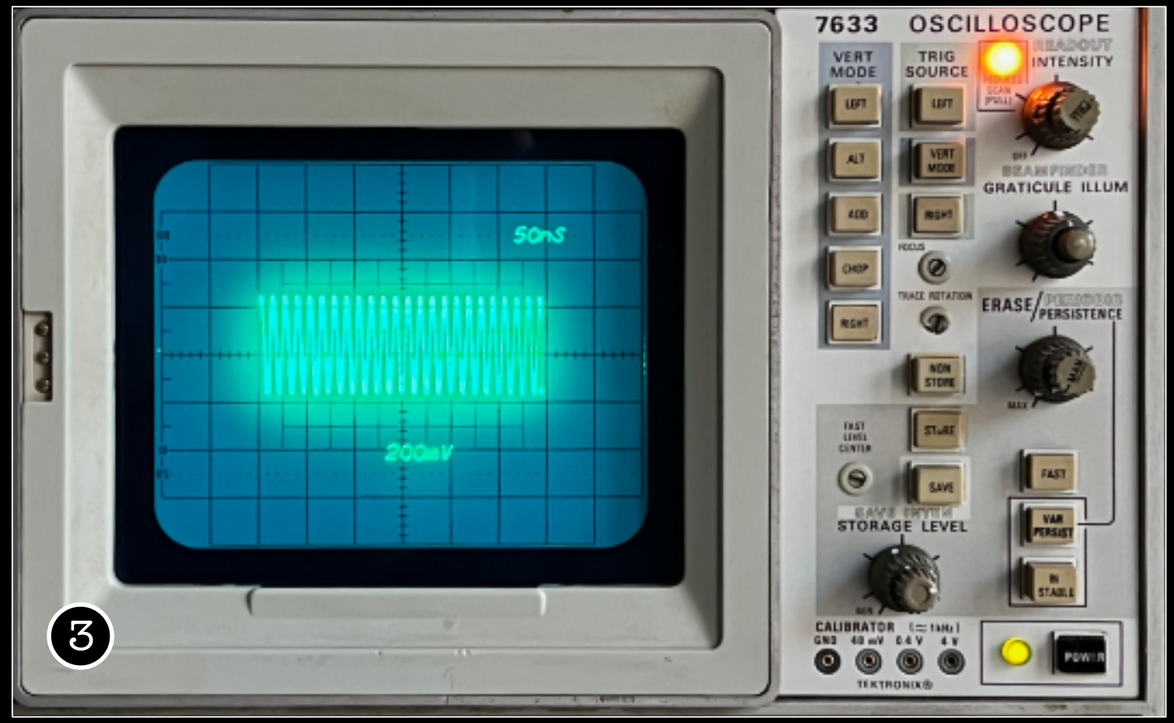
7633

the behavior of the 7623A and 7633. Both scopes are clearly not perfect, and this is not surprising (but anyway without the inconvenience of a camera!). As expected:

- *the segments at top and bottom of the sinusoid, where the vertical speed is zero and only the horizontal component is present, are drawn at about 20 div/µs and are clearly defined;*
- *the 7633 performs however something better than the 7623A (150 vs. 100 div/µs).*

I do not report pictures of the other storing modes common to both scopes, that are definitely worse, but a word of praise to both, still performing rather well after near 50 years, without any revision.

But now, let's see if the 7633 reduced scan mode, that promises 2,222 div/µs, really carries benefits or less. The answer is absolutely yes, as you can see by photo ❸ (note the REDUCED SCAN orange light on). The display is smaller and so the division size, but there is also the evident effect of the higher beam energy and the smaller spot size, due to the increased CRT cathode voltage from 1.5 kV to 3 kV (the real display is much better than my photo).



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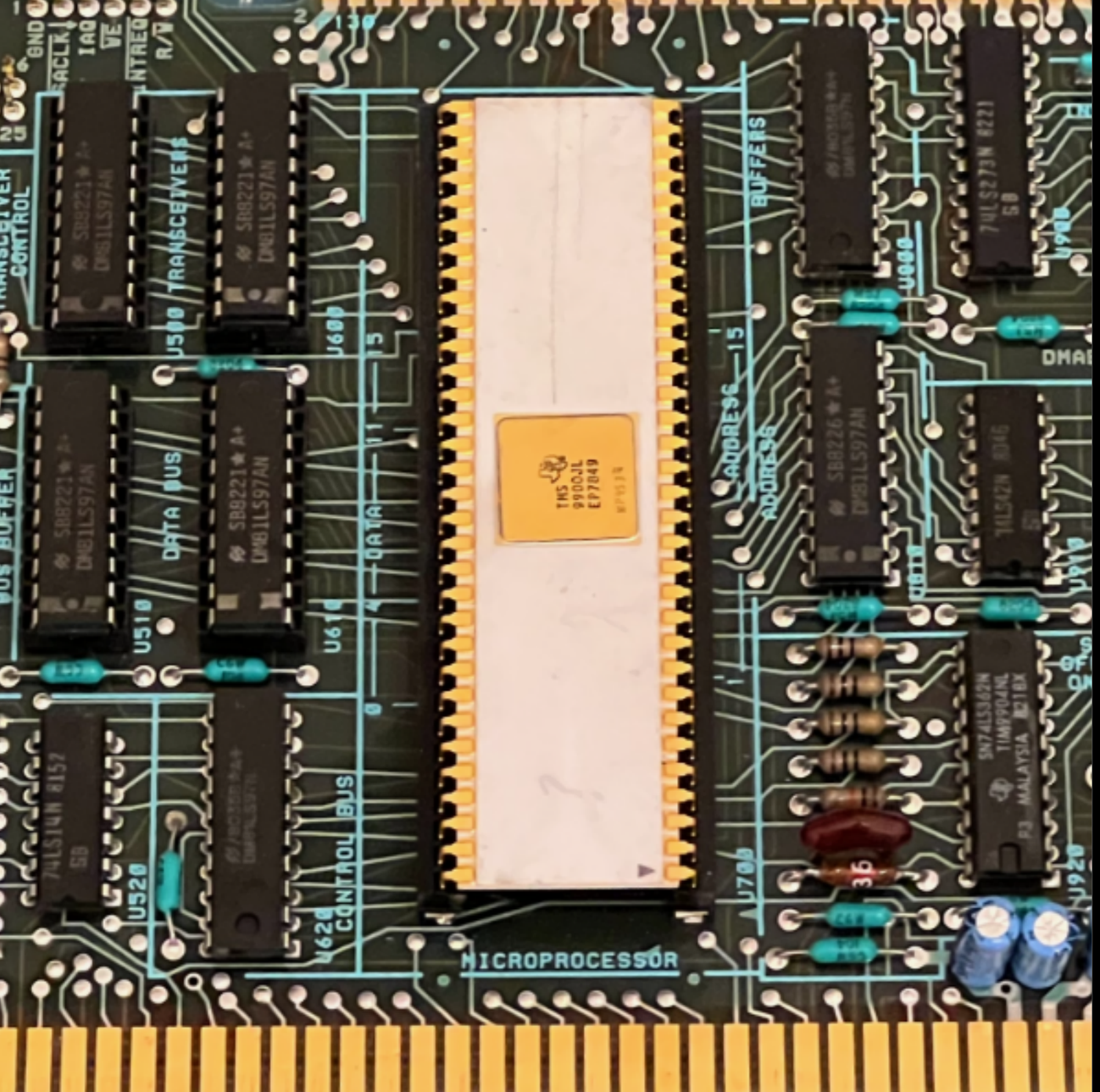


Digital storage mainframes

The 7000-Series tree has the roots when the transistors were still a novelty, but the fronds in the modern world of digital storage oscilloscopes.

The WP1100/DPO

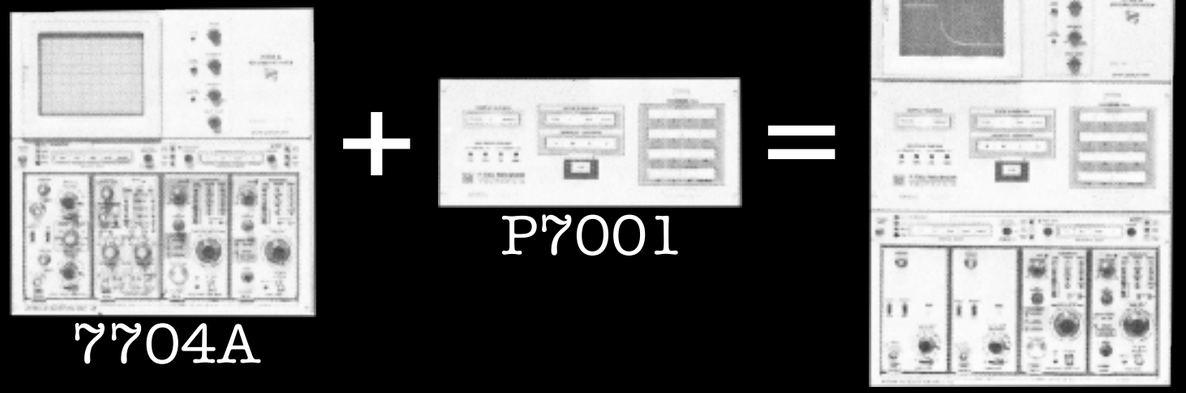
If I am not wrong, the first kind of a DSO had been presented by Tektronix in 1973, based on the 7704A, with an added piece, the P7001. It was called the Digital Processing Oscilloscope (DPO).

With reference to the 1973 advertisement page on the right, this DPO relied on the architecture of the 7704A (note the "A"), very different from the original 7404 (without the "A"), being split in two parts:

- *the Acquisition Unit, i.e., the lower half of the 7704A, with the flexibility of accepting all the 7000-Series plug-ins;*
- *the Display Unit, i.e., the upper half of the 7704A, i.e. the CRT and related controls.*

In the middle between the Acquisition Unit and the Display Unit, a new component is added: the new P7001 Processor. It has the ability to digitize a waveform, storing the digital data in a memory, and providing the capability to convert those data to analog form for display. Furthermore, the P7001 offers an interface with an external minicomputer, that can read the memory for processing and write the memory with the processed data.

So, the 7404A plus the P7001 does not compose a DPO themselves, an external unit is required to complete the cycle: a minicomputer (Tektronix used Digital Equipment PDP-11) or a programmable calculator, such as the model 31 by Tektronix, that we see on the right after the wedding.



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E03

Model 31 computer

I had no idea that also Tektronix had been producing programmable desktop calculators, like the yummy model 31, which, married with the DPO, constitutes the WP1100 waveform processor.

Nice and powerful

The Model 31 was very powerful for the times. Among other things, it used standard algebraic notation in order to evaluate mathematical expressions, with normal operator priorities: first exponentiation and root extraction, then multiplication and division, last addition and subtraction, and it was possible to change the processing order using parentheses. In other words, to evaluate 3 + 7 x 5, you had to type 3 + 7 x 5 and press "=" to get the result. The 31 featured also a complete set of transcendental functions and supported conditional branching and subroutines.

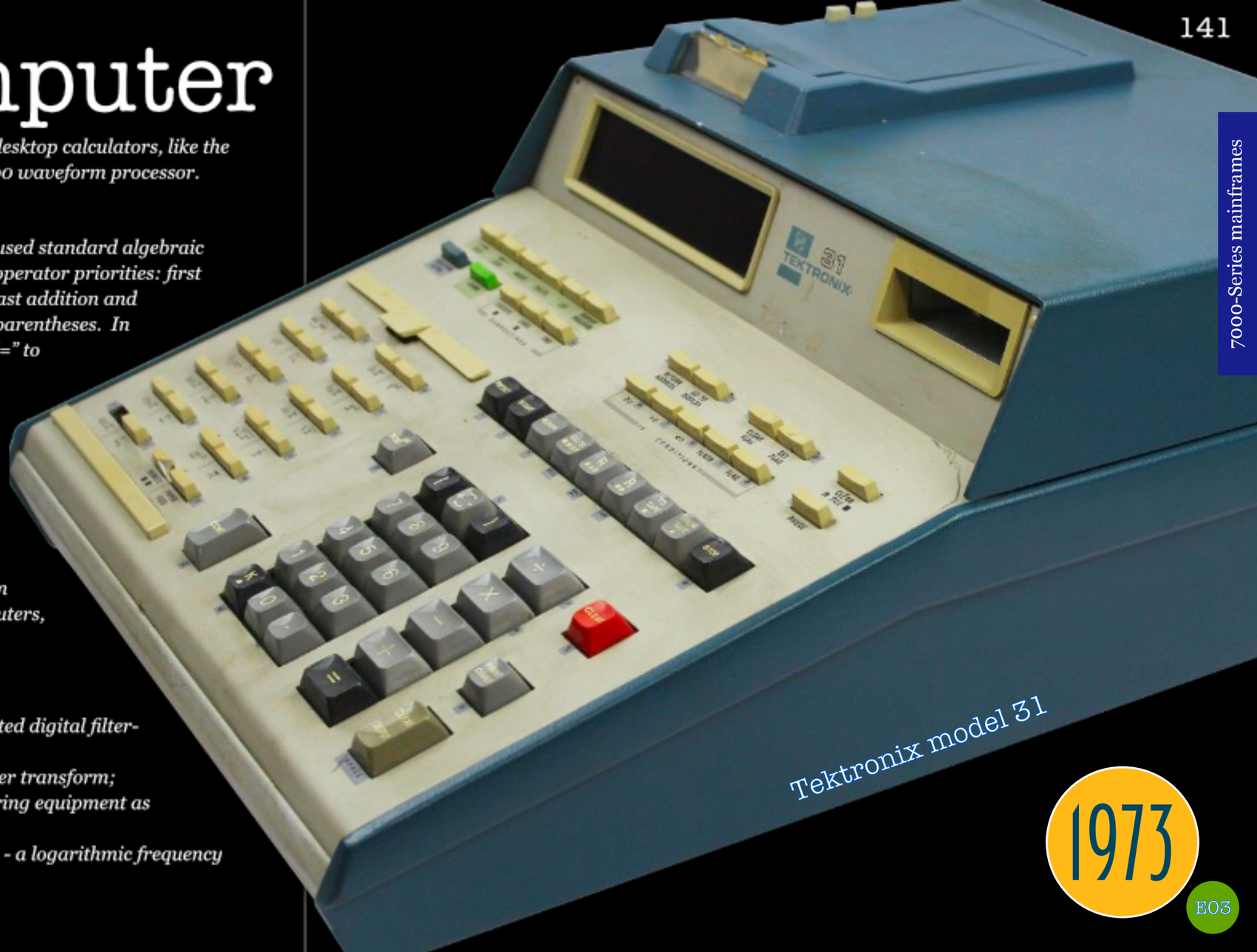
A model 21 existed, capable only to store simple programs composed by sequences of keystrokes. Both had a tape unit to store programs and data and a printer.

WP1100 Waveform Processor, what could it do?

The married couple WP1100 was not, as mentioned, the only waveform processor offered by Tektronix. Other were based on larger minicomputers, with better performances and easiness of use.

The applications of the WPs opened a new world of applications, such:

- *signal averaging to extract signals from noise;*
- *viewing of a signal after passing it through an arbitrarily constructed digital filter- one that may not even be realizable in conventional circuitry;*
- *display of a signal in the frequency domain by calculating its Fourier transform;*
- *correction of signal errors caused by such limitations in the measuring equipment as nonlinearity, small impedance mismatches, and the like;*
- *automatic scaling of a displayed waveform to any convenient form - a logarithmic frequency scale, for example.*



Tektronix model 31

1973

E03

7854, the treasure of the crown

The last, the most complex and one of the most expensive ever: king 7854 goes beyond the 7000-Series. You will forgive me for reserving a large space to one of the most intriguing electronic instruments in the history of electronics. The last scion of a generation of heroes.

His majesty 7854

Once upon a time...

*"Once upon a time" starts every tale. I started instead this tale writing: "*I don't own a 7854 and it is unlikely I will ever own one. It is too rare and too expensive. But I could not let out of this book the ultimate and most exciting expression of the 7000-Series, so I will rely for this description on the TekWiki documents and other info from the Internet".

Never say never

That was what I wrote when I decided to talk about the 7854. In the meanwhile I found a 7854 on eBay and I bought it. Later I found also the related "Waveform calculator" and bought it as well. I confirm it is expensive, but I have now a 7854 to describe here (yet not fully working).

What has the 7854 special?

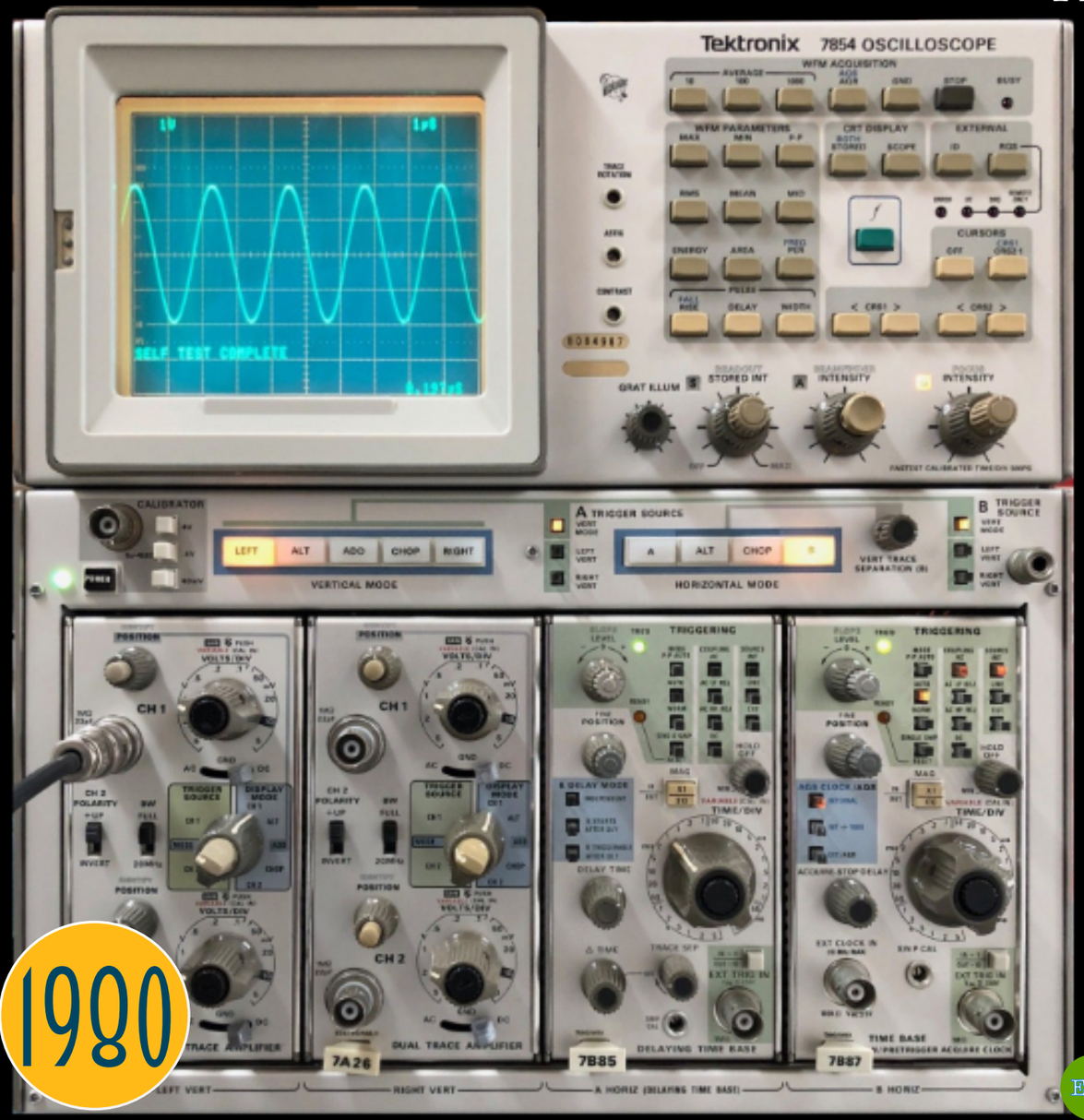
I hope I will be able to thoroughly describe this gorgeous piece of equipment, referring correctly how much more than a normal oscilloscope it is.

Externally, the 7854 is very similar to other 4-bays, scopes, like the 7704 or the 7904, and can be used exactly like those. But... the 7854 is also one of the first Digital Storage Oscilloscopes (DSO) ever. Not very performing in the single sweep mode (just 500.000 samples/second), but in sampling mode it allowed to exploit its full 400MHz bandwidth (having the proper plug-ins).

But the most exciting feature is having put together in one box:

- *a traditional top-class oscilloscope;*
- *a DSO;*
- *a programmable a calculator*
- *a Waveform Processor, for the waveforms that have been acquired by the DSO.*

To my extreme delight, the 7854 uses the Reverse Polish Notation logic, that, to be understood, of the old Hewlett-Packard calculators, like the HP-35, that my father gave me in 1973, when I was studying for the Electrotechnics exam at university.



7404A with P7001
and Tektronix 31 calculator

7854 with the
Waveform Calculator

Seven years later the WP1000

The 7854 arrives

The 7854 arrival

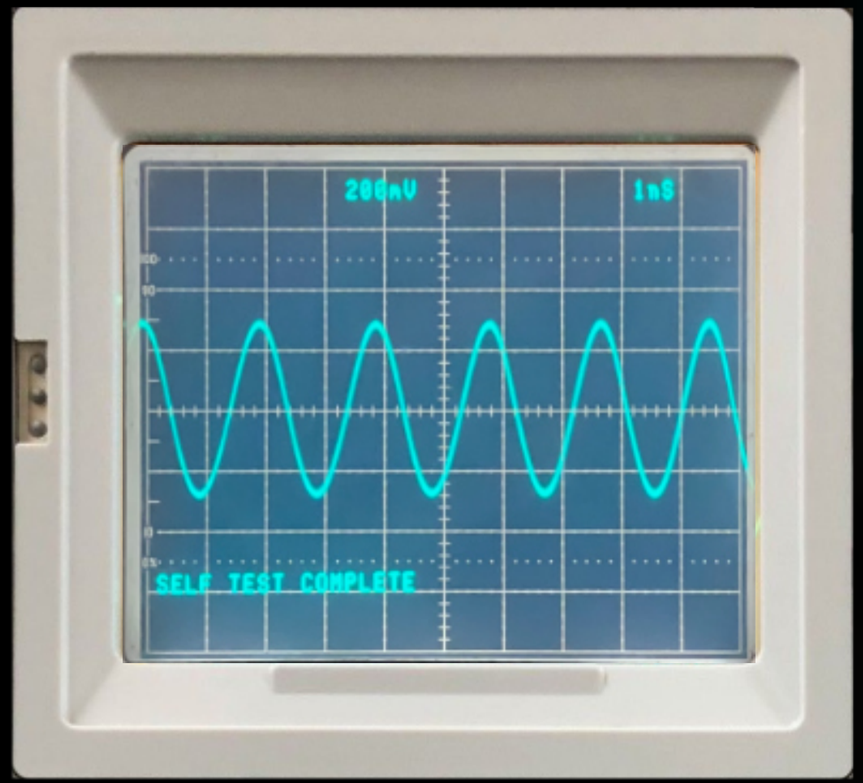
In 1973, it was perhaps too early for the DPO. It was expensive (it used magnetic core memory), its performances were low (150 k sample/sec), and, probably, computers were too new for the largest part of engineers.

Seven years later, in 1980, things were very different and the world was ready for the 7854 arrival. I am not sure that we can consider it the first commercial DSO, but I can imagine that it had however a disruptive effect. It also gave the 7000-Series a whole new range of applications, extending its lifecycle, thanks also to the 7854 capability to be used as normal oscilloscope. If you already had a 7000 oscilloscope, you could keep all yours plug-in, saving on the investment. If you didn't, you could choose among a variety of plug-ins that perhaps only Tektronix could offer, and buy however a normal oscilloscope, with a possible path to the future, that could be afforded gradually.

As you can see here in the pictures, the base concept of the WP1100 was kept unchanged, even if, as we will see, with a different and more modern technical approach.

Just like an oscilloscope

The first 7854 wonder is the SCOPE key. Pressing it, the beast becomes a doggy and behaves exactly like any other 7000-Series oscilloscope. Looking at the CRT, apart from the message "SELF TEST COMPLETE", you can hardly distinguish from, e.g. a 7904. The more evident clue is the readout calligraphy, more precise and modern. This offered also the possibility of a gradual approach to the new world, for the electronic technicians who had to afford this important step.



Let’s go digital!

Just press a key

Let’s now press the ACQ key: the realtime trace that we see on the screen is acquired and stored in memory, together with Scale factors (vertical deflection factor and horizontal sweep rate) with units, and the vertical zero reference (VZR), since all are required to fully specify the waveform values. If you want to switch from the realtime trace to see the stored trace, just press STORED. The display changes, as shown in the picture.

Memory organisation

The manual explains with a million words, examples and clarifications the general logic of the storage. I have found it a bit confusing. Here below its distillate, non really complex indeed.

There are four memory spaces where is possible to store waveforms, called WFM (Waveform Memories).

Each WFM is a space corresponding to 10 x 10 screen divisions.

- *vertically, each point is represented by 9 bit; each division is so 51.2 points high;*
- *horizontally, each point is represented by 9 bit; each division is so 51.2 points wide.*

In other words, each WFM is 512 x 512 bit.

Note however that:

- *vertically only 8 out of 10 divisions are displayed (the CRT is not square but rectangular);*
- *it is possible to raise (>P/W command) the horizontal resolution to 1024 reducing to two the number of the available WFM. Setting the horizontal resolution to 256 bit, you get instead 8 WFMs; setting to 128 bit you get 16 WFMs;*
- *the command >WFM allows copying the content of a WFM to another.*

What you see on the screen when you press STORED is not a separate memory, but is simply one of the WFM, called OPW (operational waveform). When you acquire a waveform, it goes in WFM 0 (zero) and OPW points to it (OPW 0). You can decide to make visible instead another WFM with the command WFM (and the OPW on the screen changes accordingly).

Note: All the operations described above require the Waveform calculator connected to the 7854. We will talk later about it but it was necessary here to introduce the base concepts.

The ground reference

We humble servants

An important point to always remember is that the 7854 is basically a normal 7000 scope with an added digital part. That means that, differently from modern DSOs, a human servant must be always present to help his Majesty the Processor doing its work. The most evident is that the Processor cannot go out of the box and turn the plug-in knobs. But He has the way, even if cumbersome, to read their status, decoding the readout fields on the screen. We servant must turn the knobs for Him, but He can read them.

But there is a point where our help is even more necessary: establishing the ground potential reference. His Majesty can only read the screen, the readouts and the traces, but where is the ground level? It depends on how we moved the POSITION knob on the vertical amplifier. To be more clear, if my trace is a constant line, does it mean 0V, 1V or -2.37V?

So, if we want a GND reference different from the middle of the screen, we must simply set the vertical input to ground, position the trace were we want and press the GND key. Simple and fast.

***NOTE**: these pages are not as they should, because I am still fixing my 7854. Some photos are just fillers. They will be richer in the next edition. Apologies.*

Processing the waveforms

Stored traces

Now that I have acquired and stored the waveform, I can examine it, also at a later time, even if I switched off the oscilloscope and switched it on again, provided that I connected a +6.25V power source to the two banana plug that are present on the back panel of the instrument (I thought that few mAs could be required, but the manual asks for 0.7A!).

As we saw, I can have a number of stored waveforms, from 2 to 16 depending on their resolution, so I can compare them among each other or also with a real time trace (pressing the BOTH key, obtained with the "shift" f-key first and the STORED key after).

Operations possible without the external keyboard

Also without the Waveform Calculator, that we often will call with its true name of external keyboard, many calculations can be done on the stored traces, and precisely:

- *MAX - Maximum*
- *MIN - Minimum*
- *P.P - Peak-to-peak*
- *RMS - Root mean square*
- *MEAN - Average value*
- *MID - Vertical midpoint*
- *ENERGY - Energy*
- *AREA - Area under curve*
- *FREQ - Frequency*
- *PER - Period*
- *FALL - Fall time*
- *RISE - Rise time*
- *DELAY - Delay*
- *WIDTH - Pulse width*

So, for example, display a complex waveform, press RMS and get its Root Mean Square value.

Cursors

Cursors are an important tool in an oscilloscope and, in this book, we propose more ways to get them in traditional 7000-Series scopes.

Even without the external keyboard, the 7854 gives you true, modern measurement cursors that you can activate just with a key (f+CSR1 or f+CRS2-CRS1, respectively for one cursor or two cursors). Cursors can be moved with self-accelerating CRS1<, CRS1>, CRS2< and CRS2> keys. The screen shows with a Δ sign the horizontal and vertical difference in the cursors position, taking into account the scale factors.

The “Waveform calculator”

A bombastic name

It seems clear to me that there was a precise willing to keep the general structure of the original DPO, with a something like a computer, but separate from the instrument. The proof is that the programming keyboard received the bombastic name of “Waveform calculator”, clearly dictated by the Marketing, being it just a simple passive matrix keyboard, not magnificent neither from the design point of view, but really well built and robust, with its Aluminum box.

It connects to the 7854 with a cable terminating in a DB-25 connector.

Not talking yet about programming

The keyboard adds as many as 81 keys to the 7854 (some are duplicated from the front panel). Most of them allows to give direct orders the 7854, that it can execute immediately.

We will talk later about programming; now we want still say something about the operations that we can do <u>without</u> programming. Programming is basically storing sequence of commands, with some extra capabilities.

Testing direct commands

We already saw the built-in calculations and cursors movement. Now you can try to move the traces (VPUP, VPDN), play around with the already described memory commands (WFM and WFM>) and many others that you can find on the manual.

It is time now to pass to discuss the 7854 programming approach.

Forget the Model 31

Starting from Model 31?

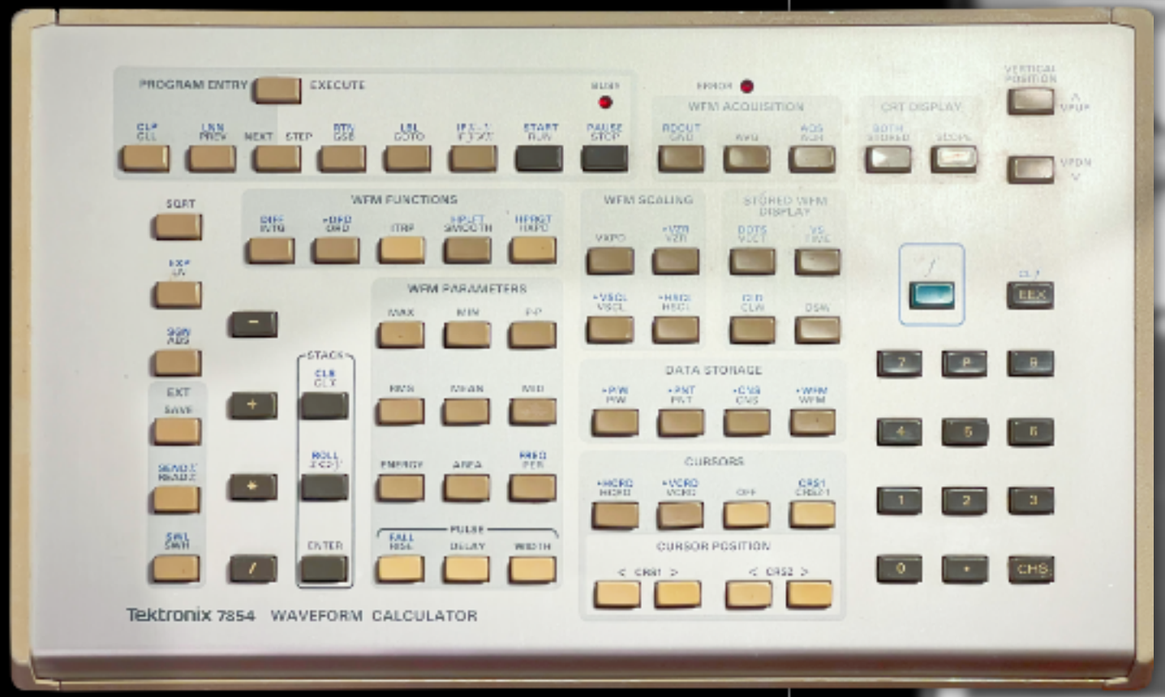
Judging from the Model 31, I could imagine that, at the beginning of the seventies, Hewlett & Packard was not alone in the field of programmable calculator. For a perfect ignoramus like me, who also babbles forty years later, it seemed logical to use this Model 31 as a starting point for the 7854.

7854 approach

So, it was weird for me, discovering that 7854 did not exploited the great Model 31 inheritance.

Going to change things, I could expect a more modern (for the time) approach, e.g. with a BASIC interpreter, like the HP-85 desktop computer, that had a large impact on the market and on the technical trends.

Tektronix decided a different strategy, abandoning the model 31 and choosing instead a paradigm nearer to the Hewlett & Packard handheld calculators, as we will see next.



HP calculators

The beginning

Hewlett & Packard, or shortly HP, entered the market of the calculators in the sixties, copying the Olivetti Programma 101, defined by many as "Desktop Computer" and considered by a part of computer historiography to be the first personal computer in history. The US company reached an out-of-court settlement, awarding Olivetti a royalty fee of US$900,000 *(from Wikipedia).*

The 9600 tabletop calculators

In 1975, I knew nothing about Olivetti and Programma 101, but I was in love with the HP-9600, far away from my economic capabilities like the Andromeda star. So I tried in any way to reproduce it with a Fairchild F8 microprocessor, with some success, also on the commercial side.

The handheld calculators

But I was not alone, not able to buy an expensive programmable calculator, so HP focused on creating something smaller and more affordable. The first result was the HP-65, followed by the 67 and the 97. They had an incredible success and were the opportunity for many to get acquainted with the electronic computing.

Also the HP-67 remained a dream, because when I had the money to buy it, it was no longer up-to-date and attractive for me, until few years ago, when I bought one in the States (see its photo here on the left), discovering what I did not understand at that time, i.e. that it was not so practical to use as I thought. In reality, those key coordinates used as opcodes, made its programming almost more difficult than using directly the octal opcodes on the PDP-8 panel switches!

But, even if complex, people could easily understand them, thanks also to the very good HP manuals and promotional leaflets, finding a possible way to fulfill their even complex calculation requirements.

Why that choice?

It must be like that!

The result has been that 7854 uses a programming language and a general logic very similar to HP-handhelds, I suppose not by chance. Most of the commands, when not specifically linked to waveform processing, have even the same names. The only differences that I noted are >CNS and CNS instead of STO and RCL.

Why?

Which were the reasons of this choice? Searching in the various documents that I could find on TekWiki, I found precise answers in an article by Val Garuts and Jim Tallman, of Tektronix, published by Electronics magazine on March, 13 1980 ("On-board digital refines scope processing measurements").

The first reason is that "extending a language like Basic so that it would be able to perform waveform operations would dilute its familiarity. Using a key-stroke language, each function is represented by a single labeled key. The system's capabilities are easy to learn and remember." *Another advantage of a key-stroke language was that* "it permits one-finger push-button operation, which is more at home in the lab than two-handed typing".

The real reason?

But the real reason, I believe, is confessed later, after having spoken in favor of the RPN logic: "further forcing the choice is the fact that more engineers are familiar with RPN". *Clearly, they couldn't explicitly write that most technicians were using HP calculators.*

Follow the leader

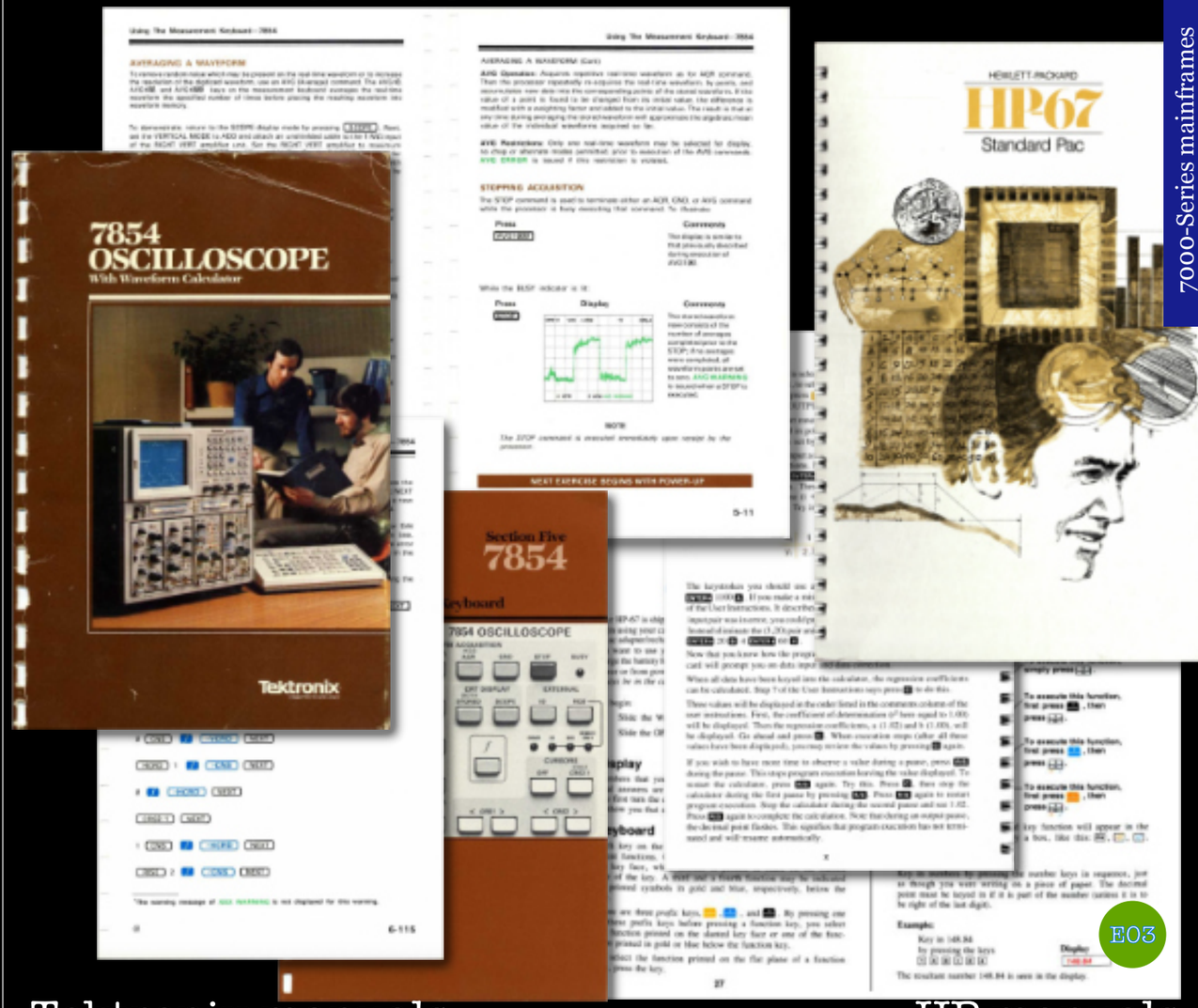
So, in the end, also Tektronix fell to the charm of this kind of programming and eventually also the good 7854 documentation resembled the HP's one, as shown here on the left.

This is not a criticism: on the contrary, I appreciate the Tektronix capability to accept and embrace new good ideas, even if from direct competitors. Not many other companies would.

Great Tek!

Tek had the great merit of putting together the best: the unmatched 7904 oscilloscope (with all the benefits of the 7000-Series), with the advantages of the HP calculators' logic, but furthermore removing their biggest limits, thanks to the large and neat CRT display; a concrete improvement over the numeric micro-display of the HP calculators.

Despite all that, in my humble opinion, in 1980 the time of dedicated keyboards had passed: the coeval HP-85 had now a full ASCII keyboard, and a BASIC interpreter could have been perhaps a better choice. But I am happy today that the 7854 kept this programming system, so wonderfully cumbersome and amusing for us toys players...



Tektronix manuals

HP manuals

A 25-kgs calculator

Personal notes

I never could have imagined, after all these years, that I would still be talking about the Reverse Polish Notation, that had a great importance for me in 1976, when I started producing one of the first personal computer, based on Fairchild F8 microprocessor, that used a language named RPN-8, that I wrote completely using machine codes, without even an assembler. Hard to believe, it was really used to write real accounting programs, the were really utilized in the field. Later I wrote a BASIC interpreter for the Z-80, which had the algebraic expression parser and that was thousands times better that the RPN-8. Here you can find here the original manuals and much other stuff: http://www.k100.biz/z.Computer/index.htm.

Differences

Coming back to RPN, it was cumbersome but in some way practical and effective. I don't want to bother you with the nth Yet Another RPN Explanation, telling you how can do 3 x 8 with a 7854, but I find interesting to note two things:

- *differently from the HP calculators, the 7854 has five stack register instead of four, with the W register added;*
- *(!) each register may contain a number or a waveform (really a pointer to a WFM).*

Waveform Processor

The content of the X and Y registers are always displayed on the CRT. When the X or Y register contain a waveform, the display says "n WFN", with n = number of the WFM. As you have certainly imagined, that opens an entire new world: you can execute operations with waveforms like they were numbers! So, for example, if you have a trace with a voltage and a trace with the related current, you can produce a new trace with the instant power, just multiplying them each other.

In the same manner, you can apply any function on them (EXP, LN, etc...). Now I really understand what a Waveform Processor is...

Programming the 7854

A key for a statement?

The programming logic is definitely similar to HP calculators: a key correspond to a mnemonic that appears on the screen when pressed. E.g., you press a key and you get on the screen "IF x=y". The result is that the listing, thanks to the screen, is rather easy to read and to understand, while the data entry makes almost impossible to make typo errors: you cannot write "IF x=q".

Someway like some human languages based on ideograms, the problem with this type of logic is that when you extend the language, you should increment the number of keys or exploit key combinations, and that is his limits. HP-67 had "only" 35 keys; it was so necessary to assign up to 4 meanings for each key, using three prefix keys f, g and h. The HP-67 bigger sister HP-97, otherwise exactly the same machine but with an added printer, had however 56 keys and could so reduce the prefix key to just one (f). The Tek WC has 81 keys and can thus rely on a single "f" function key.

The reverse Polish Notation

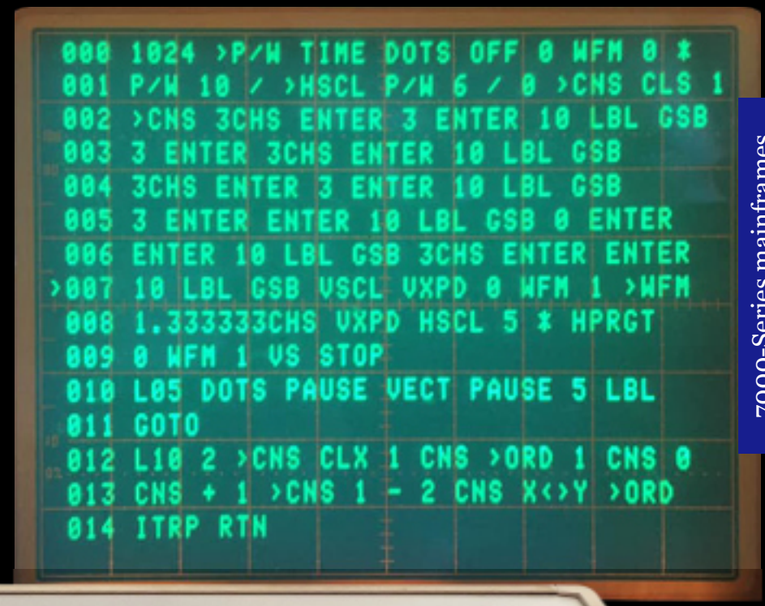
We loyal to HP calculators were convinced of the absolute superiority of the Reverse Polish Notation (RPN); perhaps it was not so, but still now I am more comfortable with it than parentheses, and keep in my iPhone an HP-35 emulator that I use instead of Apple calculator.

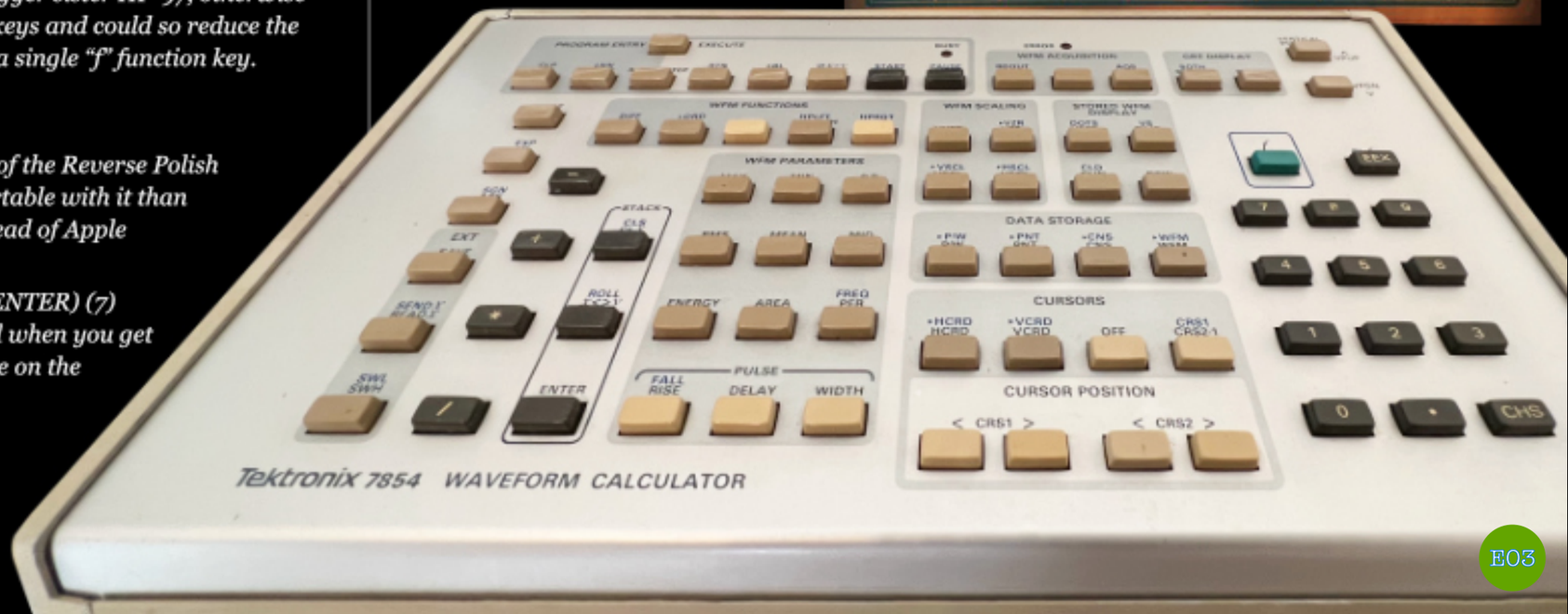
With the RPN, if you want to calculate 3 + 7 x 5, you have to type (3) (ENTER) (7) (ENTER) (5) (x) (+). Not very intuitive at beginning, but very practical when you get used to. You can find more info on the 7854 user manual or everywhere on the Internet.

Years later, writing my first programming language interpreter, I understood that it was simply for me the way to save a fair amount of complexity and code, not an advantage for the user. But RPN was our flag and we were its proud soldiers...

The 7854 language

Anyway, the chosen method was, all in all, not so bad, and the Tektronix implementation in the 7854 was good enough. The result is still today not despicable.


000 1024 >P/W TIME DOTS OFF 0 WFM 0 *
001 P/W 10 / >HSCL P/W 6 / 0 >CNS CLS 1
002 >CNS 3CHS ENTER 3 ENTER 10 LBL GSB
003 3 ENTER 3CHS ENTER 10 LBL GSB
004 3CHS ENTER 3 ENTER 10 LBL GSB
005 3 ENTER ENTER 10 LBL GSB 0 ENTER
006 ENTER 10 LBL GSB 3CHS ENTER ENTER
>007 10 LBL GSB VSCL VXPD 0 WFM 1 >WFM
008 1.333333CHS VXPD HSCL 5 * HPRGT
009 0 WFM 1 VS STOP
010 L05 DOTS PAUSE VECT PAUSE 5 LBL
011 GOTO
012 L10 2 >CNS CLX 1 CNS >ORD 1 CNS 0
013 CNS + 1 >CNS 1 - 2 CNS X<>Y >ORD
014 ITRP RTN

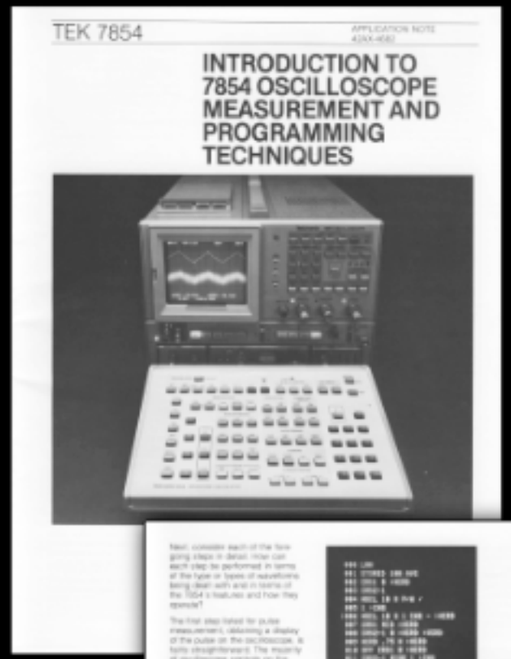


Programming for what?

We talked with great enthusiasm of the 7854 capability to be programmed. But what can we do with it? These are some examples taken from the Tektronix document "7854 APPLICATION PROGRAMS":

- *Amplitude comparison in dB;*
- *Reversing waveform in time;*
- *Logarithmic sweep display;*
- *Running maxima and minima;*
- *Characteristic impedance (Zo) from a TRD display;*
- *Area of X-Y display;*
- *Time jitter measurement;*
- *Period measurement of eight cycles of a waveform;*
- *Rise-time with cursor positioning;*
- *Pulse width with cursor positioning;*
- *Rise-time from 20% to 80% level;*
- *Pulse symmetry measurement;*
- *Building waveforms;*
- *Averaging waveforms;*
- *Standard normal distribution and one-sided probability test;*
- *Storing data as a waveform and standard deviation;*
- *Least squares estimation;*
- *Envelope mode;*
- *Simultaneous XY and YT;*
- *Gain and phase measurement.*

Another interesting document that you can download from TekWiki is "Introduction to Tektronix 7854 oscilloscope measurement and programming techniques".


TEK 7854

APPLICATION NOTE

INTRODUCTION TO 7854 OSCILLOSCOPE MEASUREMENT AND PROGRAMMING TECHNIQUES

Programming thru GPIB (IEEE 488)

We talked before about the 7854 native programming and gave same examples of what we can do. The 7854 can be however programmed also by an external processor, like the old DPO, using the IEEE 488 interface.

What is it?

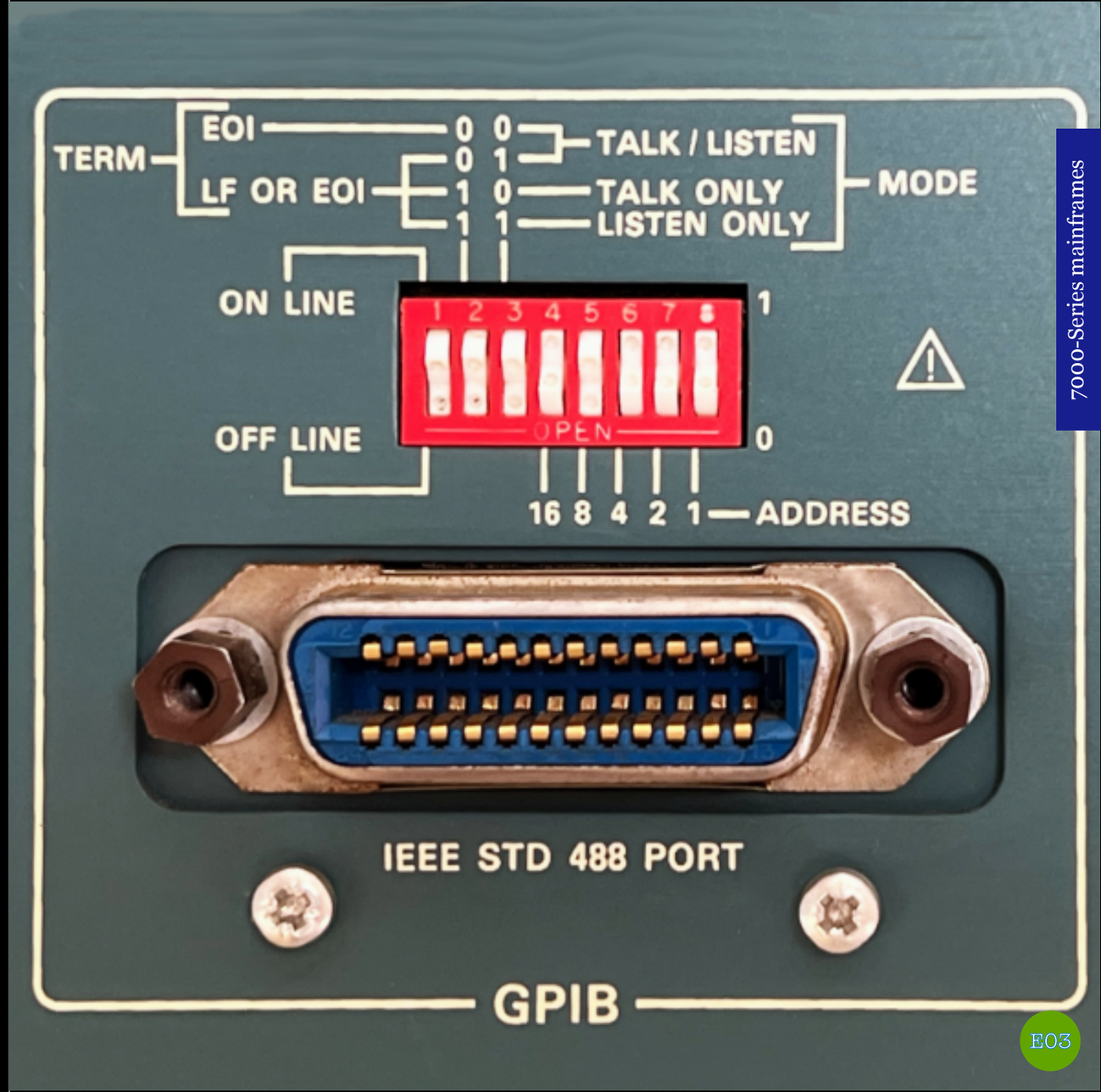
IEEE 488 is a parallel interface bus developed by Hewlett-Packard as HP-IB (Hewlett-Packard Interface Bus). It is today generically known as GPIB (General Purpose Interface Bus). Thanks to it, you can plug your GPIB devices together without encountering any mechanical or electrical difficulties. The GPIB became the subject of several standards. Initially (IEEE 488.1), the IEEE formalized the mechanical, electrical, and basic protocol parameters, but said nothing about the format of commands or data that were defined subsequently, but that happened years later the 7854, so it has no interest for us.

7854's GPIB interface

So, beyond being a powerful stand-alone measurement and analysis tool (differently from the DPO), the 7854 can also be used as a system component, because it contains a IEEE 488 (1978) interface. Thus, the 7854's capabilities and capacities can be further extended by adding a GPIB compatible desk-top computer or a minicomputer. The combination can be for any purpose, from simply providing more program and waveform storage space to providing additional computational power.

Getting plugged in

I am going to test this 7854 capability, but I am aware of the related difficulties. I need a proper interface and a processor where to run a proper BASIC interpreter (an MS-DOS computer?), that can send commands/data to the 7854 and read data back from it. It will be a job to do after the incoming 7854 restoration. I will keep you informed.

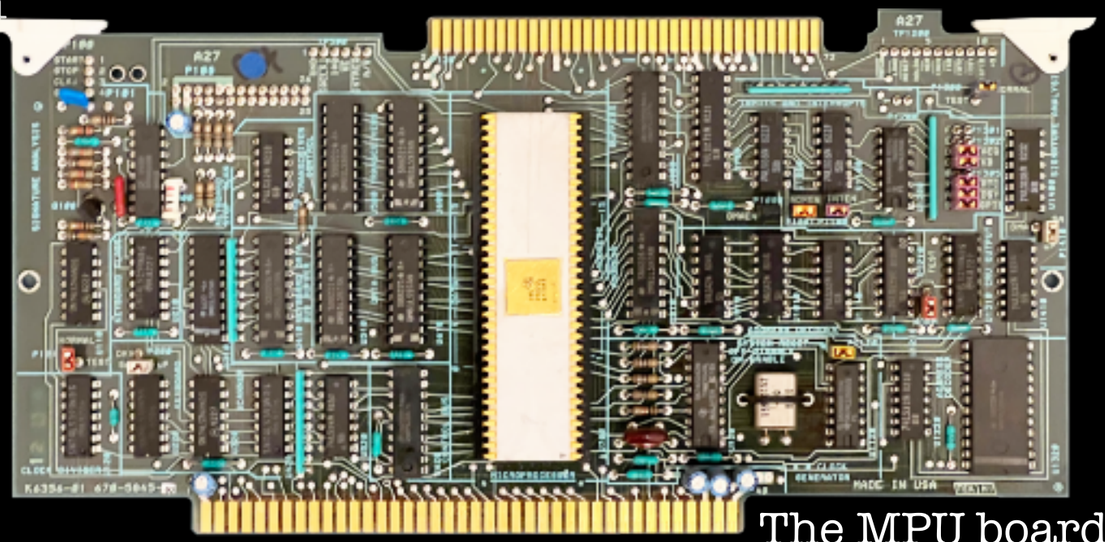


The Tektronix designers did a great job, and succeeded putting the 7854 in the same volume as the 7904 and other 4 slot housings (apart from the small rear protrusion of the fan). In the space of the calibrator, the readout board and the HV module, they put an entire computer composed by seven boards and an interconnecting plane in a very neat assembly:

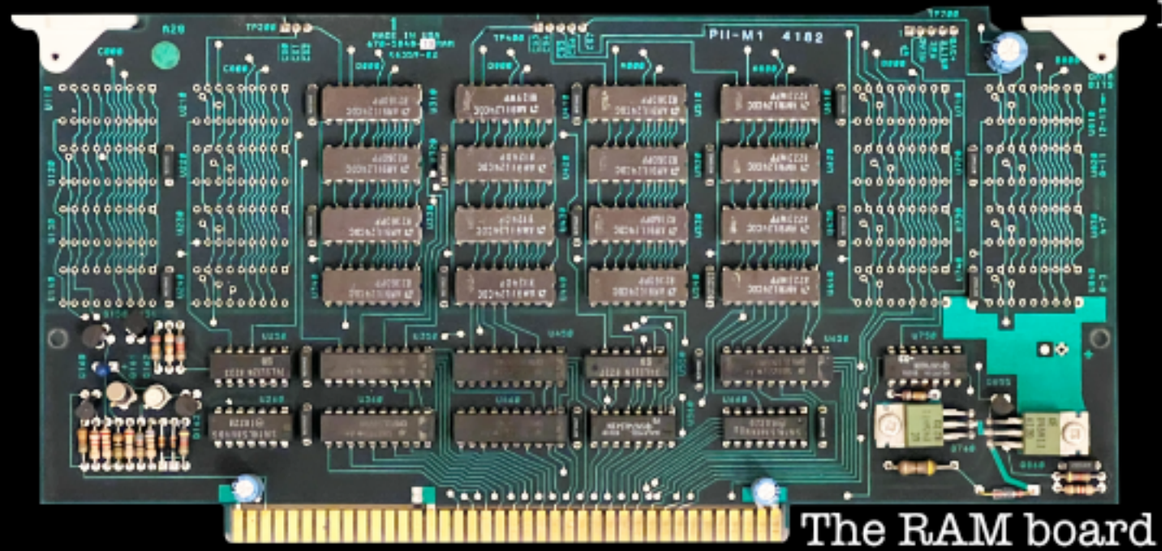
- *the MPU board;*
- *the RAM memory board;*
- *the ROM board;*
- *the GPIB interface board;*
- *the display board;*
- *the logic board;*
- *the acquisition board (in the photo here).*

Note in this picture the rear part of the DC controlled fan motor and the robust rack where the boards are allocated. The Aluminum cover has been removed to show the details of the acquisition board.

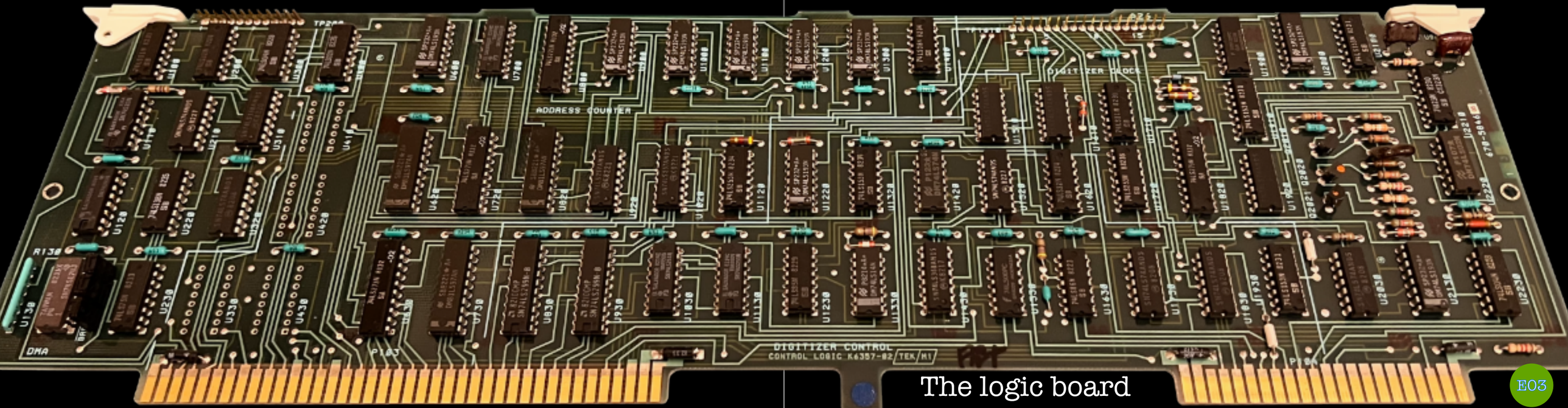
7854 digital boards



The MPU board



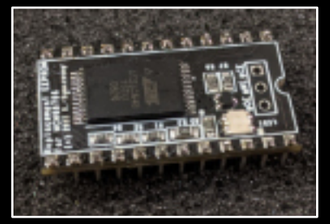
The RAM board



The logic board

The terrible ROMs

One of the more common problems with the Tektronix 7854 is ROM rot. Over time, the Mostek mask ROMs start losing bits. It's a well known issue that has been discussed online a number of times. The problem appears or with a total black-out or, more frequently, with a self test code shown at start-up on the front panel big pushbuttons lights, as shown in the photo below. There are various strategies to fix this problem.



❶ The best overall solution is to use the alternative to the original ROM designed and produced by engineeringideas (https://www.ebay.it/itm/155133430035). It has a low profile and the same 24-pin size of the ROM and uses modern components (here in photo on the left).

❷ Substitute the ROMs with with pin-to-pin compatible MCM68764 EPROMs (or MCM68766), programming them with the same original code that you can download from TekWiki (you need to use the same suffix as yours, e.g. 150-0408-00). Note that the CY7C264 is NOT GOOD, because it has a different A10, A11 and A12 pin assignment.

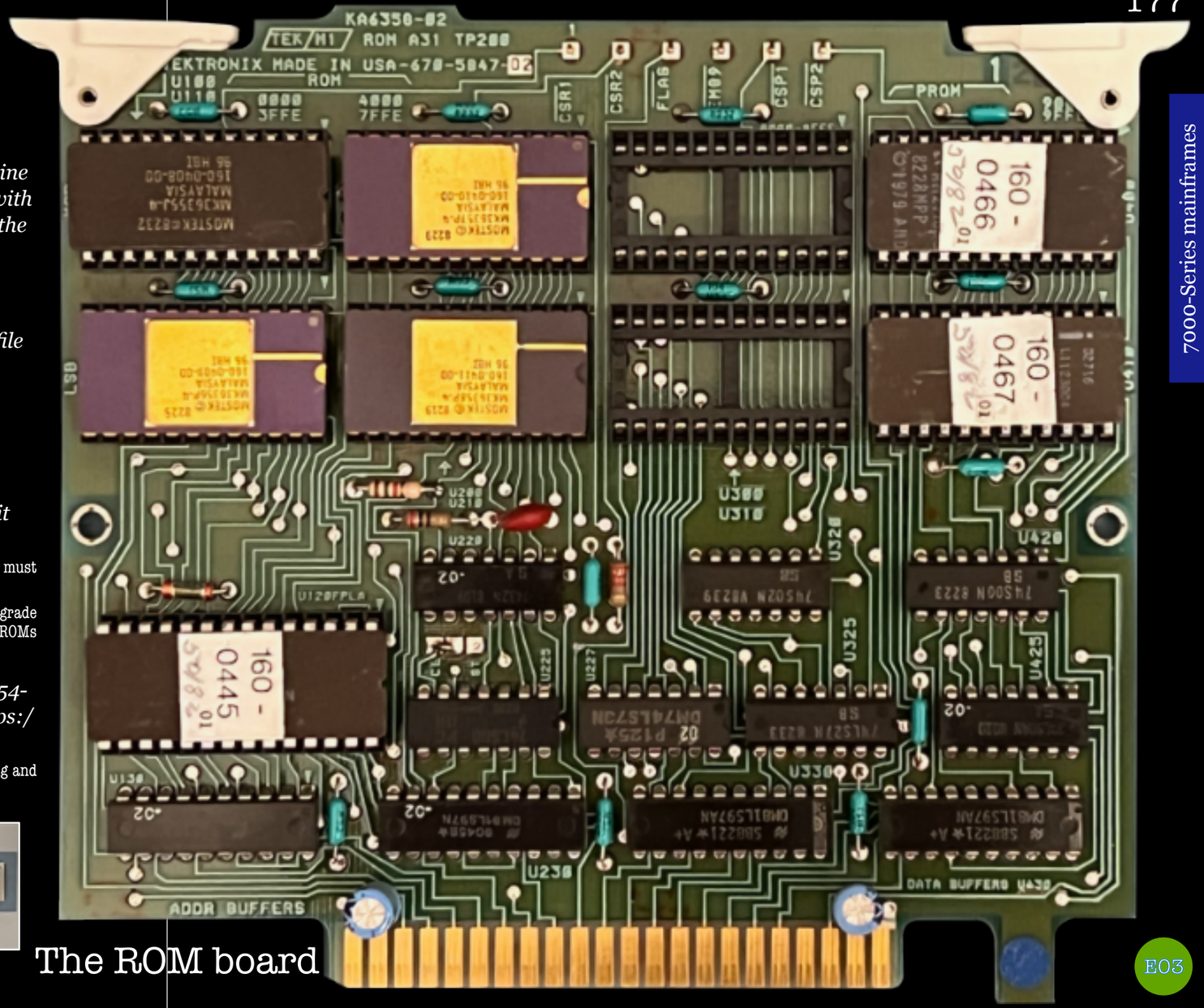
In both cases don't forget to set the CL/ST jumper to STatic. The original ROMs work only in clocked mode, i.e. the /CS signal must return high after every read. That is the reason because I could't read them as 2764, even with an adapter that I built.

The two U400-U410 2716 should not have problems, unless also the U120 PLA is damaged. The three are used only to upgrade the ROM. So, if you use the n+1 version of the ROM, you can remove them. E.g., I have -00 ROMs and -01 EPROMs. Using ROMs -01 I could remove the EPROMs.

❸ The VintageTEK Museum suggests a different alternative (https://vintagetek.org/7854-mostek-mkb36000-rom-repairs/), using two 27128 EPROMs, with an adapter from https://store.go4retro.com/2364-adapter/ and some modification work.

This adapter is not good, as you could think, to just use 4 x 2764 in place of the ROMs, because the adapters are 28 pin long and the ROM space is only 24 pin.

The ROM rot error code on the big pushbuttons (forget the VERT LEFT light that is not involved)



The ROM board

The display board

The 7854 display board seems rather over-complicated at first sight. In the first eighties I designed a very simple board using the TMS9929, an exceptional (for those years) video display controller, son of the 9918 used in Commodore and other microcomputers (designing the board was straightforward, then I spent several months writing its software…). But the market available VDCs were all designed for a raster display, so probably no integrated solution existed and Tektronix had to study a board with a limited integration level.

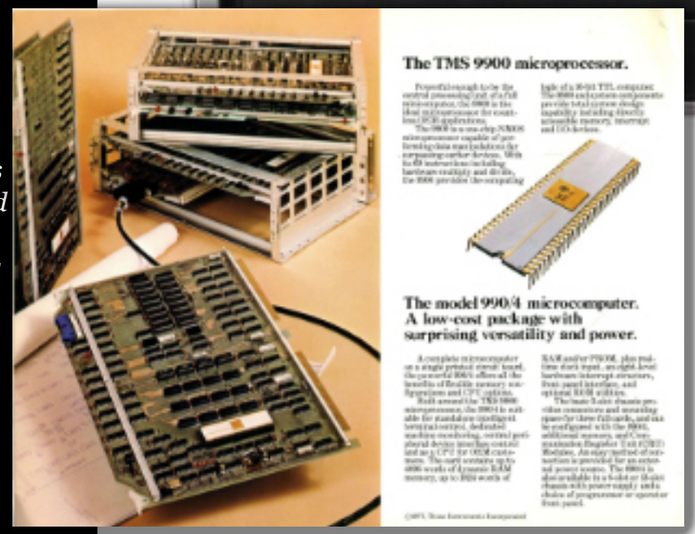
Clearly, the GPIB controller uses instead an LSI, the 156-1246-01, as shown in the photo, marked SC80909LD. I could not find any info about this, neither on TekWiki. According the Tektronix internal "Common design part catalog", this chip should have been -00, while the -01 was based on Motorola MC6848BLD, but I got nothing on both.

The GPIB board

TI-9900
an old flame of mine

So the 7854 uses a TMS9904 CPU... Very strange for me, I had a peculiar experience with this family of microprocessor. I had personally lived the exciting microprocessor revolution era. Every day a new component came out, new solutions, new families of microprocessors. You could barely study one that another was already out on the market, confusing all your ideas. I clearly remember when Texas Instruments launched the TI-990 family, much more than a Z-80 or a 6800: 16 bit, with an architecture worthy of a mini... Immediate love... But I could only study it rather deeply, because the course of life took me elsewhere.

Few years later, in 1979, TI decided to afford the personal microcomputer market, with the TI-99/4. At that time, I used to sell microcomputers like VIC-20, ZX-Spectrum and others. It was a surprise to find the mythical TI-990 in a low cost product, which outperformed all competitors by far. Also its quality was very good, and we got very few returns. Many reasons, and among them the lack of third-party software, led TI to a price war with Commodore, a US$330 million loss in the third quarter of 1983 and to the end of the TI-99/4.



“On-line” help

Today every kind of instruments has the so-said “on-line help”, normally a synthetic copy of the manual stored in memory, that can be recalled on the screen. At the time, memory was a scarce s.

The 7854 was however a disrupting product, and the 7000-Series users were not yet acquainted with such a complexity.

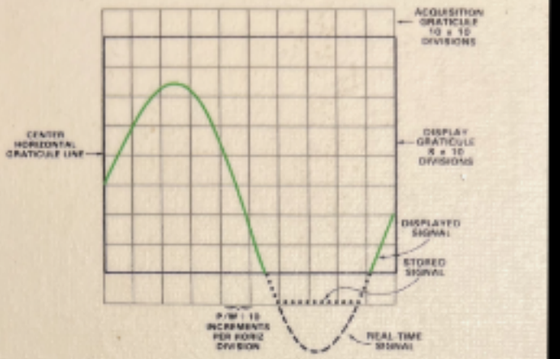
The solution was so a micro-manual, with just 4 plastic sliding cards, mounted on top of the 7854, Not very technological, but certainly practical. An absolute novelty, that we cannot find in other instruments of the series. A sign of attention to user problems.

The plastic cards are rather robust, but maybe that not all the surviving units have them still today, so I have tried to reproduce them with a certain precision in the following pages, so that the pictures may be used to recreate new cards.

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Qty	1 2 3 4 5	Name & Description	Mfr Code	Mfr Part Number
1-1	352-0573-00			1		HLDR,INSTR CARD:ABS	80009	352-0573-00
-2	070-2848-00			1		CARD,INSTR:OPERATORS	80009	070-2848-00
	070-2849-00			1		CARD,INSTR:OPERATORS	80009	070-2849-00
	070-2850-00			1		CARD,INSTR:OPERATORS	80009	070-2850-00
	070-2851-00			1		CARD,INSTR:OPERATORS	80009	070-2851-00

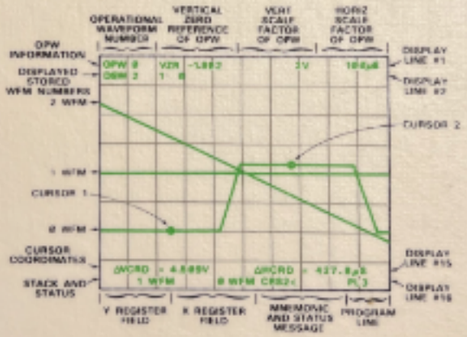
ACQUIRED WAVEFORMS

Real-time waveforms within the acquisition graticule are stored in memory with AQR, AQS , or AVG commands.


ACQUISITION GRATICULE 10 x 10 DIVISIONS
CENTER HORIZONTAL GRATICULE LINE
DISPLAY GRATICULE 8 x 10 DIVISIONS
DISPLAYED SIGNAL
STORED SIGNAL
P/W / 10 INCREMENTS PER HORIZ DIVISION
REAL TIME SIGNAL

STORED DISPLAY

Stored Waveforms are displayed in the STORED or BOTH display modes.



The operational waveform is the last waveform in the X register and is the operand for all WAVEFORM PARAMETERS and FUNCTIONS.

The vertical zero reference (VZR) is the displacement in divisions of the waveform zero from the center horizontal graticule line.

Refer to 7854 Operators Manual for complete instructions.

070-2848-00

PROCESSOR OPERATION

The digital processor in the 7854 operates using RPN (Reverse Polish Notation). The stack is the operator's primary input port to the processor and consists of five storage registers (X, Y, Z, T, and W):

W	T	Z	Y	X
1E+99	1 WFM	23K	50.73µ	Ø WFM

X & Y registers displayed in line 16 of STORED & BOTH modes. Constant registers Ø-49 (Ø-99 with Opt. 2D) are accessed by CNS, >CNS.

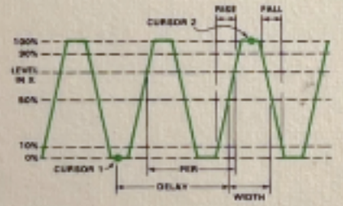
Changing the points per waveform (P/W) setting with >P/W drastically effects the waveform memory, stack, and display.

WAVEFORM MEMORY FORMAT

OPTION ØD		STANDARD				OPTION 2D			
P/W	512	128	256	512	1024	128	256	512	1024
# OF WFM'S	1	16	8	4	2	40	20	10	5

Waveforms and points are numbered starting from Ø.

PULSE PARAMETER DELIMITERS



PER and FREQ use vertical crossing level in X register (use MID, MEAN, computed, or entered value).

Refer to the 7854 Operators Manual for complete instructions.

070-2849-00

ERRORS

Error Message	Mnemonic(s) Effected	Possible Cause(s)*
AQR ERROR	AQR (Acquire Repetitive)	2, 3
AQS ERROR	AQS (Acquire Single-Shot)	2, 3, 5
AVG ERROR	AVG, AVG10, AVG100, AVG1000	1(c), 2, 3
CHS ERROR	CHS (Change Sign)	1(a)
CLL ERROR	CLL (Clear Line)	13, 14
CLP ERROR	CLP (Clear Program)	13
CLW ERROR	CLW (Clear Waveform)	1(b)
CNS ERROR	CNS (Return Constant)	1(h)
>CN ERROR	>CNS (Store Constant)	1(h)
CRS ERROR	CRS1>, CRS1<, CRS2>, CRS2<	6, 7
DEL ERROR	DELAY (Return Delay Time)	21
DIF ERROR	DIFF (Differentiate)	1(g)
DSW ERROR	DSW (Display Stored Waveform)	1(b)
FAL ERROR	FALL (Return Fall Time)	7, 9(b), 21
FRE ERROR	FREQ (Return Frequency)	1(a), 9(a)
GND ERROR	GND (Set Ground Ref.)	2, 3
GOT ERROR	GOTO (Go To Program Line)	1(j)
GSB ERROR	GSB (Go To Subroutine)	1(j), 20
HCR ERROR	HCRD (Cursor Horiz. Coord.)	6
>HC ERROR	>HCRD (Set HCRD)	1(a,s), 6, 8
HPL ERROR	HPLFT (Horiz. Position Left)	1(a,f)
HPR ERROR	HPRGT (Horiz. Position Right)	1(a,f)
>HS ERROR	>HSCL (Set Horiz. Scale Factor)	1(a,k), 8
HXP ERROR	HXPD (Horiz. Expand)	1(f)
INT ERROR	INTG (Integrate)	1(g)
ITR ERROR	ITRP (Interpolate)	1(m)
LBL ERROR	LBL (Return Labeled Line Number)	1(n), 17
LNN ERROR	LNN (Begin Label)	13, 16
NEX ERROR	NEXT (Go To Next Line)	13, 14
ORD ERROR	ORD (Return Ordinate)	1(a,f)
>OR ERROR	>ORD (Set Ordinate)	1(a,f), 22
>P/ ERROR	>P/W (Set Points/Waveform)	1(p)
PER ERROR	PER (Return Period)	1(a), 9(a)
PNT ERROR	PNT (Return Point Value)	1(q)
>PN ERROR	>PNT (Set Point Value)	1(q), 12, 22
PRE ERROR	PREV (Go To Previous Line)	13, 15
RIS ERROR	RISE (Return Rise Time)	21
REA ERROR	READX (Input X Register Value)	4, 11
RDO ERROR	RDOUT (Return Readout)	1(d)
RTN ERROR	RTN (Return From Subroutine)	19
RUN ERROR	RUN (Run Program)	14, 18
SAV ERROR	SAVE (Save Program)	4, 14, 18
SEN ERROR	SENDX (Output X Register Value)	4
SMO ERROR	SMOOTH (Smooth Waveform)	1(e), 10
STA ERROR	START (Start Program)	18
TEX ERROR	TEXT (Output Text)	4
>TE ERROR	>TEXT (Input Text)	4
VCR ERROR	VCRD (Cursor Vert. Coord.)	6
>VC ERROR	>VCRD (Set VCRD)	1(a), 6, 9(b)
VPD ERROR	VPDN (Vert. Position Down)	12
VPU ERROR	VPUP (Vert. Position Up)	12
VS ERROR	VS (X Versus Y Mode)	1(b)
>VS ERROR	>VSCL (Set Vert. Scale Factor)	1(a,k)
VXP ERROR	VXPD (Vertical Expand)	1(a), 12
>VZ ERROR	>VZR (Set Vert. Zero Ref.)	1(a,r), 12
WFM ERROR	WFM (Recall Waveform)	1(b)
>WF ERROR	>WFM (Store Waveform)	1(b), 10
WID ERROR	WIDTH (Return Width)	7, 9(b), 21

*** See following card for explanation of error causes.**
Refer to 7854 Operators Manual for complete instructions.

070-2850-00

ERRORS (cont.)

Possible Error Causes (see preceding card)

1. X register value (X) is outside allowed limits. (See a. through s. below for applicable limits.)
   a. (X) must be a constant
   b. Ø ≤ (X) ≤ (maximum waveform number)
   c. 1 ≤ (X) ≤ 1023, AVG only.
   d. Ø ≤ (X) ≤ 7
   e. Ø ≤ (X) ≤ 2
   f. Ø ≤ (X) ≤ (maximum horiz. value)
   g. (X) must be a waveform
   h. Ø ≤ (X) ≤ 49 or Ø ≤ (X) ≤ 99 w/option 2D
   i. (X) rounded to nearest integer
   j. Ø ≤ (X) ≤ 999
   k. Ø < (X)
   l. Cursors off: (X) must be a constant >Ø, (Y) must be a waveform
      One cursor on: (X) must be a constant >Ø, (Y) must be a waveform
      Both cursors on: (X) must be a waveform
   m. Cursors off: Ø ≤ (X) ≤ (maximum horiz. coord.)
      One cursor on: Ø ≤ (X) ≤ (maximum horiz. coord.)
      Both cursors on: (X) must be a waveform
   n. Ø ≤ (X) ≤ 99
   p. (X) must be 128, 256, 512, or 1024
   q. Ø ≤ (X) ≤ (P/W − 1)
   r. −2Ø ≤ (X) ≤ 2Ø
   s. Ø ≤ (X)
2. Too many real-time waveforms selected.
3. Vertical plug-in unit in chop mode.
4. GPIB off line or improperly selected.
5. 7B87 improperly set or not in B HORIZ compartment.
6. Cursors off.
7. Cursor 2 off.
8. In VS mode (X-Y display).
9. a. OPW does not cross level (X) twice in same direction.
   b. OPW does not cross designated level.
10. (Y) must be a waveform.
11. Improper incoming data format.
12. All points of waveform must remain within the vertical data limits.
13. Command received in program Execute mode.
14. Edit line is end-of-program.
15. Edit line is ØØØ.
16. Syntax error; follow with CLL or two digits.
17. Label not in stored program.
18. No stored program.
19. No return pointer.
20. Ten or more GSBs without a RTN.
21. |ΔVCRD| < VSCL * 6E−4.
22. (Y) must be a constant.

Refer to 7854 Operators Manual for complete instructions.

070-2851-00

Some comparison

Let's see how different the mainframes main amplifier are.

Vertical amplifiers

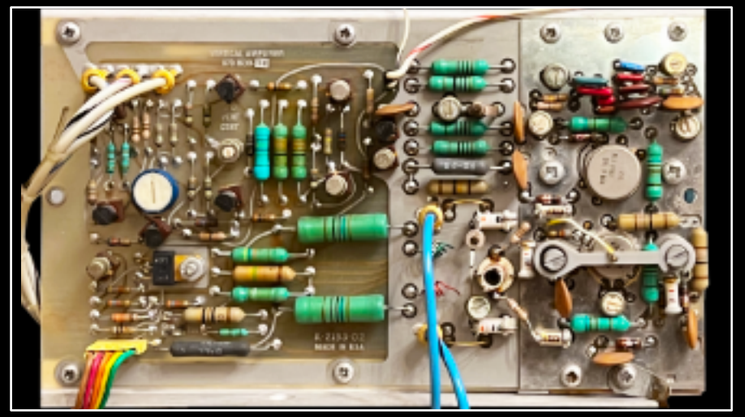
When you look at them separately, they seems to be very similar each other. So I put them side-by-side, making evident that none of them has a double.

I could imagine that the ancestor 1971 7904 had been evolved for the 1974 7844 and the 1980 7854; they seems to be just an evolution of the same design.

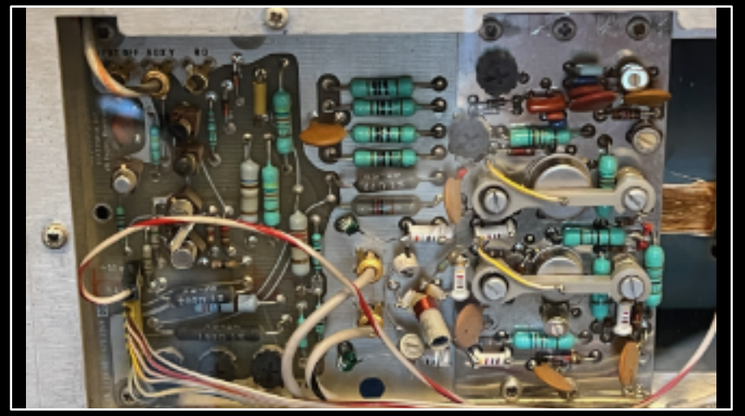
The 7603 is the bandwidth/cost-reduced version, whilst the 7933 had to add some complexity to manage the storage CRT.

7603

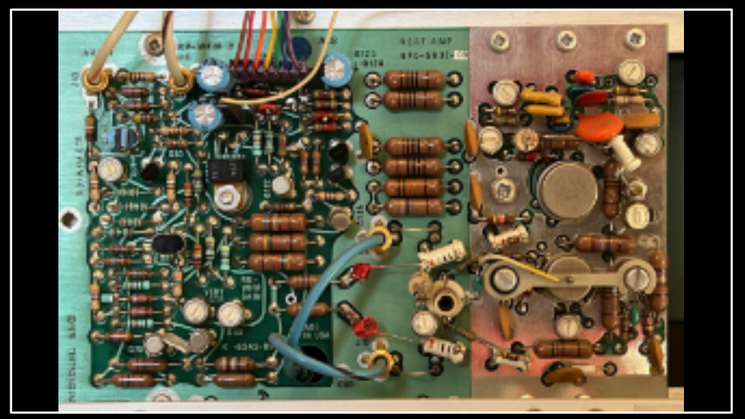
7633



7904



7844



7854

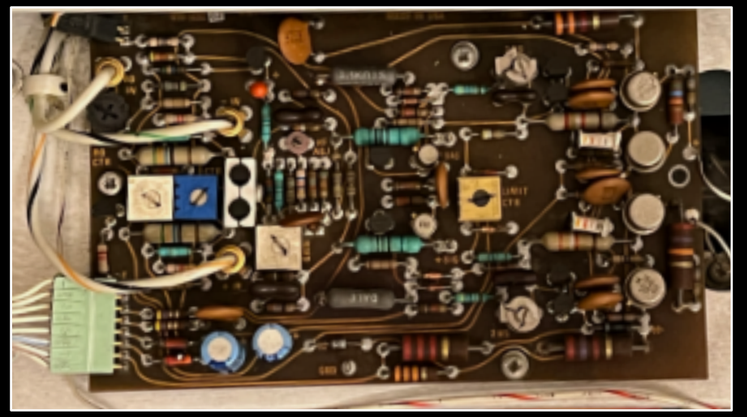
Horizontal amplifiers

Here again we can see the evolution in the horizontal amplifier layout. The 7844, that as you know has two horizontal amplifiers, seems to have the most complex design, perhaps having to manage the complexities of the dual-beam CRT, while the 7904 and the 7854 seems to be more similar. Funny that each new edition added a transistor couple with common dissipator.

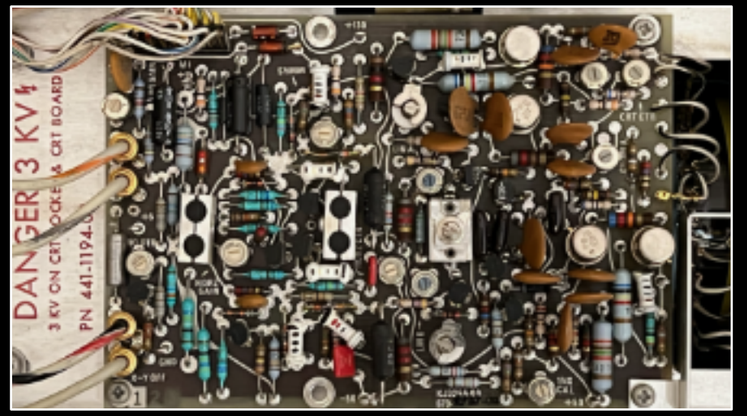
The 7603 and the 7633, limited to 100 MHz, seems to be very similar. Both adopt the 155.0022 Tektronix custom IC that drastically reduce the component count.

7603

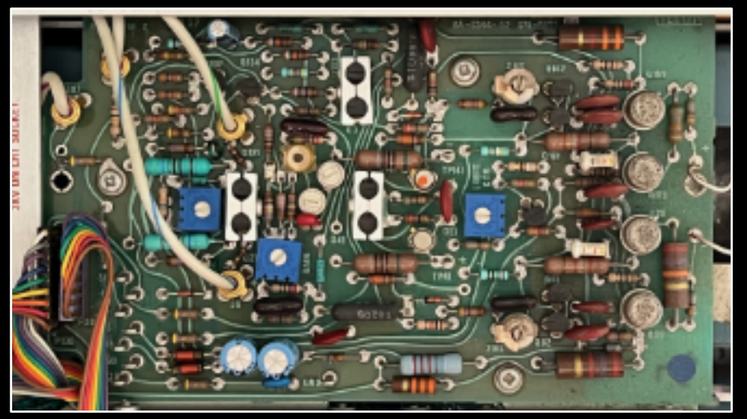
7633



7904



7844



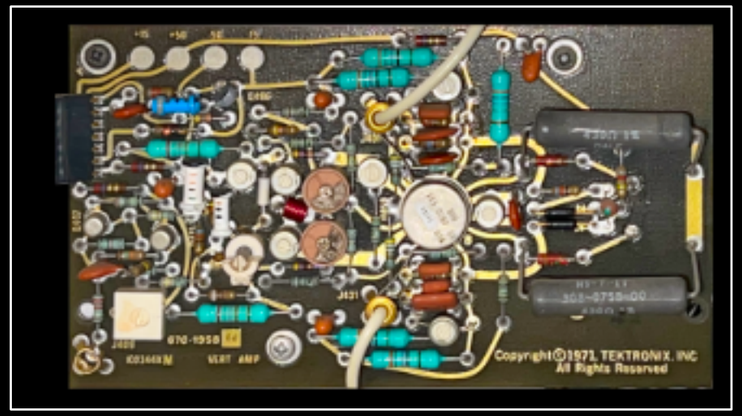
7854

Z-axis amplifiers

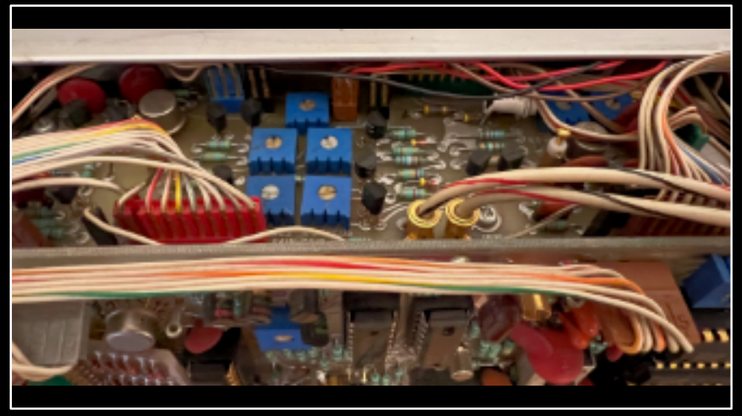
The Z-axis amplifier again sees complete different layouts, even if the 7904 and the 7854 seems to have a very similar base design, besides the integrated HV circuit of 7904 (if you cannot find it... the 7854 Z-axis amplifier is in the fan compartment).

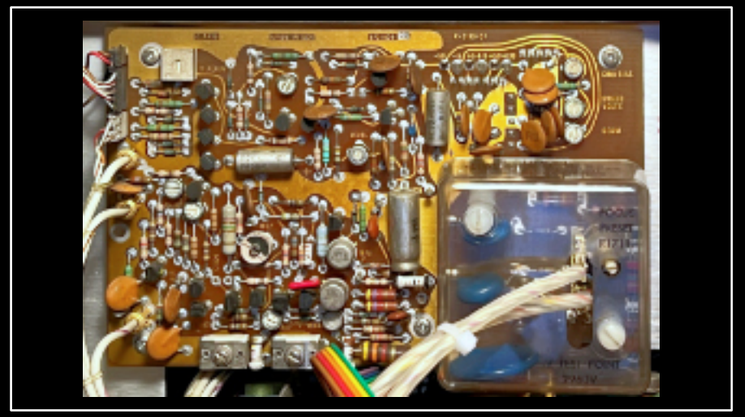
As expected, the 7844 has a completely different board (they also are two for unit). The 7603, again, has reduced the package count with an integrated circuit.

7603



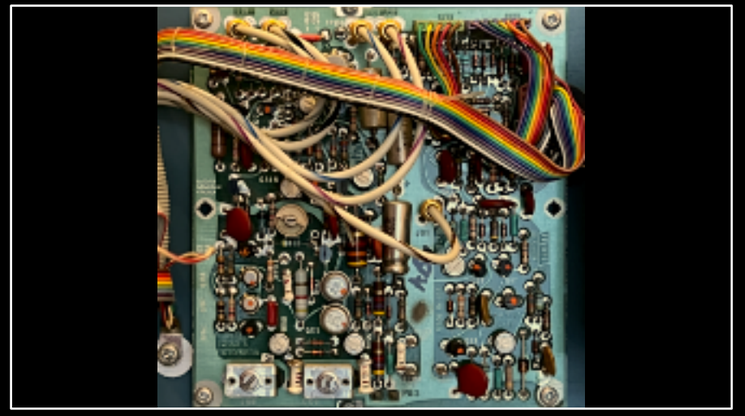
7633





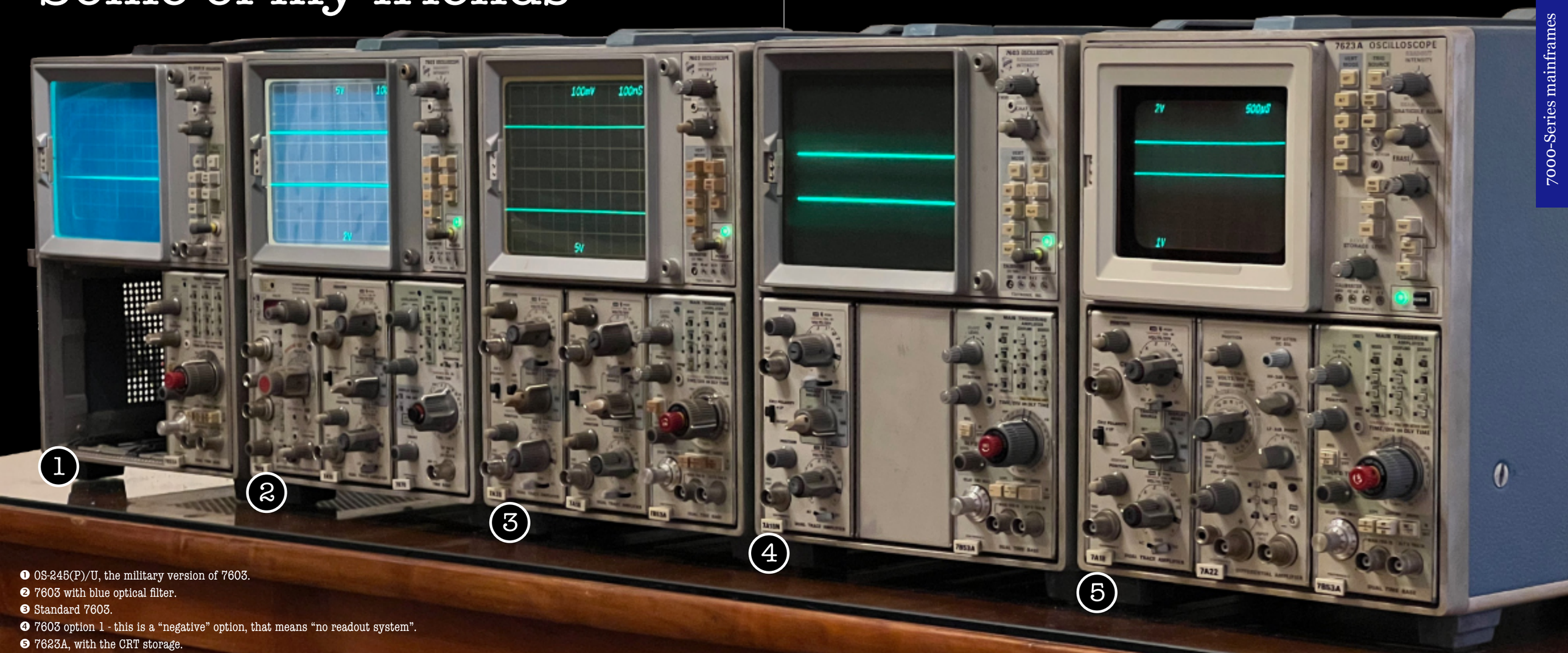
7904

7844



7854

Some of my friends



❶ OS-245(P)/U, the military version of 7603.
❷ 7603 with blue optical filter.
❸ Standard 7603.
❹ 7603 option 1 - this is a “negative” option, that means “no readout system”.
❺ 7623A, with the CRT storage.

Analog plug-ins

Plug-ins were the winning weapon of the 7000-Series. Herein, some photos and notes about a few of them.

A plug-in for everything

Tektronix (and not only) has been producing dozen of plug-ins.

Each "drawer" is identified by an acronym: the first letter is always "7", for the 7000-Series. Then there is a letter that specify the plug-in function:

- *A - Amplifier unit*
- *B - "Real time" time-base unit*
- *C - Curve tracer*
- *D - Digital unit*
- *L - Spectrum analyzer*
- *M - Miscellaneous*
- *S - Sampling unit*
- *T - Sampling time-base unit*

The third number is the model number.

According to the information available on the net, I could count about 65 different models. Some of them are very complex, such as the spectrum or logic state analyzers.

In the photo here above:

❶ 7A26, two channels, 200 MHz vertical amplifier

❷ 7A22, single channel, 1 MHz differential vertical amplifier; input sensitivity reaches down to 10 µV/Div

❸ 7A18, two channels, 100 MHz vertical amplifier

❹ 7A13, 100 MHz differential amplifier, with adjustable DC offset shown via a LED panel meter, up to 10,000 divisions. Input impedance can be set up to to "approximately infinite".

❺ 7B53A, 100 MHz dual time base, the most common on 7000-Series. Introduced in 1973 and produced until the discontinuation of the 7000-Series in 1992.

❻ 7B70, a 200 MHz time-base with no delay function. For delayed-sweep applications, the 7B70 is operated in conjunction with the model 7B71 delaying timebase. The 7B70/7B71 were primarily intended for the 7704 mainframe.

Some analog plug-ins

In the next pages, some of the most famous plug-ins are briefly described, those introduced together with the 7000-Series or shortly later.

Besides some flip-flop or gates, all of them are mostly analog.

Note the 7A13, present both in analog and digital group, having received in 1976 a new built-in digital voltmeter and the related display.

1969-1976

1969

1969

1969

1971

1973

1974

In this page the plug-ins are placed in chronological order. The short descriptions in the following pages are generally ordered according their name.

1974

1976

1976

7A12 vertical amplifier

The Tektronix 7A12 is a 120 MHz dual-trace vertical plug-in for 7000-Series scopes. In my opinion, it is a very peculiar device for more reasons. First, because I like very much its unique look, with as many as forty typical Tektronix push buttons on the front panel, twenty of which replace the traditional rotary knobs for the channel attenuators (10 per channel).

Another attractiveness for me is the use of relays in the signal path, to set the attenuation level. We already talked about the Tektronix relay technology. I started distrusting these components, but ended up liking them, perhaps because they are so peculiar and out of fashion. As presented in the last part of this book, they can also be often rescued, exercising them in the proper way, when they are not definitely broken.

Moreover, this 7000-Series plug-in allows compensating large dc offset voltages (±500 divisions); however the offset voltage is not available on the front panel to be measured externally as with the 7A11.

7A12 circuit

The 7A12 is composed bye the following main modules:

- *the attenuators;*
- *the input amplifiers;*
- *the amplifiers;*
- *the switching logic.*

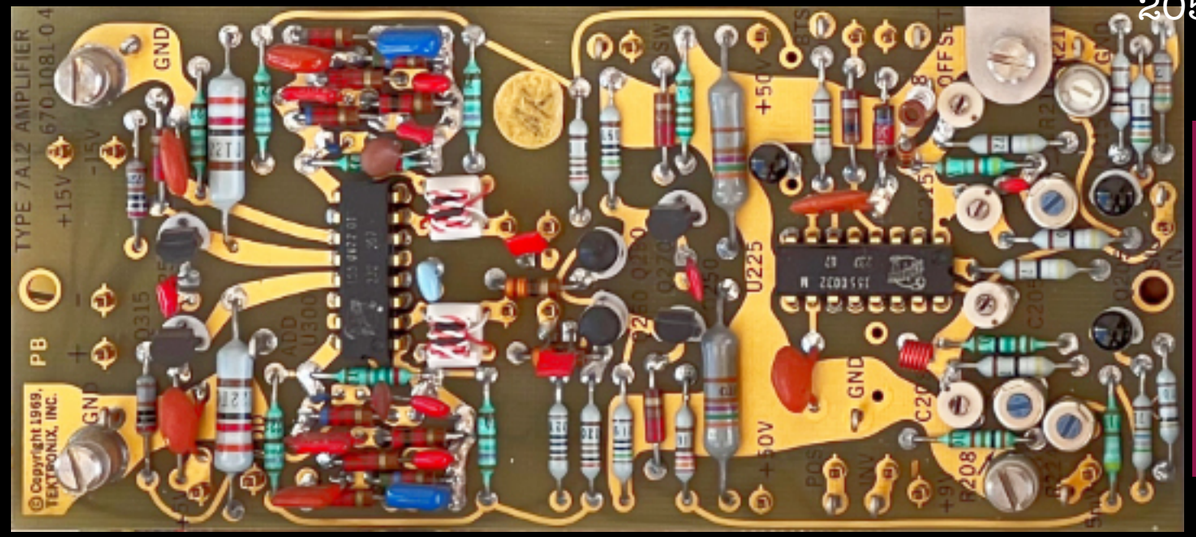
The main board contains the interfaces to the mainframes and carries the attenuators and the amplifiers.

*The **attenuator** is the part which we will have more probability to work with, so I give here some information that I hope useful. The amplifier is designed to have a deflection factor of 10mV/div, so, if we want to observe a greater signal, we need to attenuate it properly. The attenuator is composed of 4 stages: X100, X10, X5 and X1 (X1 = maximum gain). Each stage is inserted or excluded by a relay. Perhaps to make easier the command logic, the first two 7A12 attenuators (X100 and X10) have a inverted command, but this don't modify the general operation (the inversion is performed by Q60 and Q70). The table shows how the various attenuators are inserted and which are the trimmers to use for the calibration. But how does the 5mV position work? It uses no attenuation (direct link), like the 10mV position, but doubles the amplifier sensitivity, thanks to a dedicated input on the U225 (driven by Q205).*

	X100	X10	X5	X2	Corner	Top
5mV						
10mV						
20mV				X	C19B	C19A
50mV			X		C16B	C16A
0.1V		X			C13B	C13A
0.2V		X		X	Check	Check
0.5V		X	X		Check	Check
1V	X				C10B	C10A
2V	X			X	Check	Check
5V	X		X		Check	Check

*The 7A12 **amplifier** circuit is almost entirely built on a custom IC, U225, the Tektronix M55 (P/N 155-0032-00), a variable-gain transconductance amplifier, monolithic, integrated circuit in a 16-pin DIP; a very modern architecture for those days.*

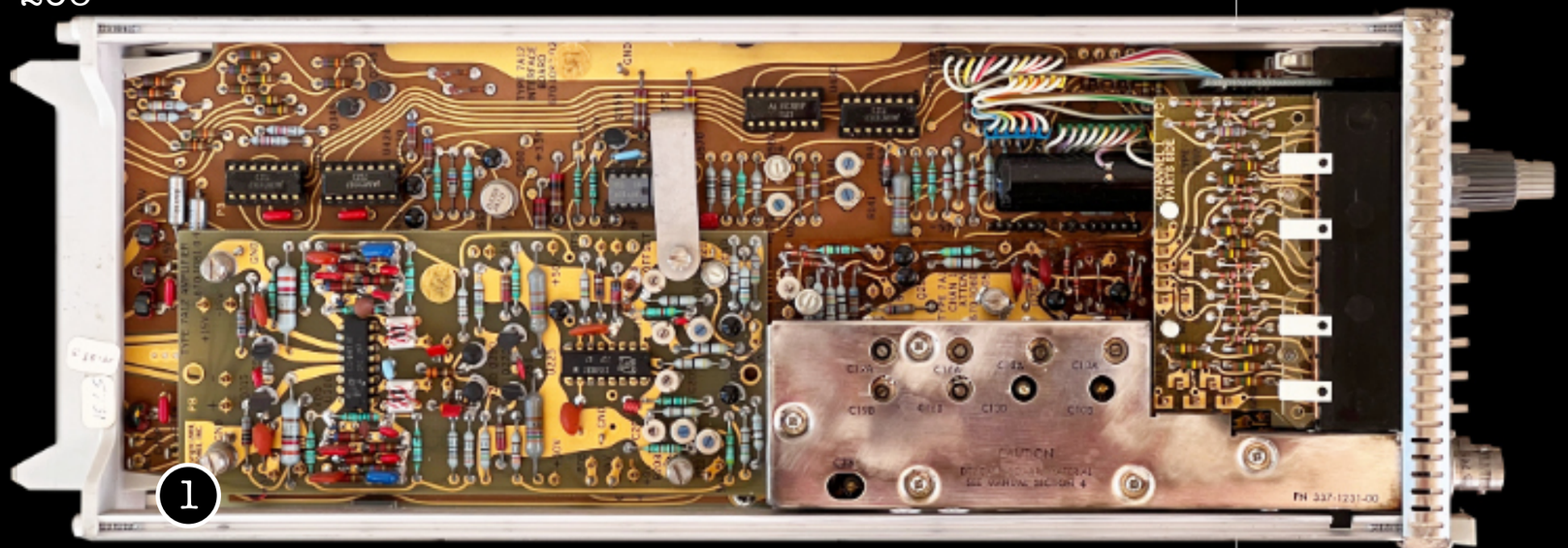
*According TekWiki, at a later time the chip designers themselves criticized it "...*This is an undesirable way of doing variable gain control, but neither Roy nor I knew that at the time. It is a noisy configuration. At the 0% signal gain there is lots of noise gain. It has poor thermal balance at anything other than 100% and the not very useful 0% signal gain. In between 0% and 100% gain, the circuit is poor in noise and thermal balance..." *(this behavior of regretting previous works is absolutely standard for us electronic designers 😬 ...) and subsequently the chip was replaced by an improved one (155-00216). But maybe that it was not so bad, considering that it was adopted in many other projects, including the super-successful 465/475 oscilloscopes series.*



*Both amplifiers are built on their own boards, and the two boards are identical. A touch of genius: although this identity, each board carries a part of the very interesting **switching logic** for the vertical DISPLAY MODE and the TRIGGER SOURCE, based on another custom IC, that we will find almost identical in many other plug-ins.*

*The **vertical signal switch** stage obeys LEFT, ALT, ADD, CHOP and RIGHT push buttons, determining which input (CH1 or CH2) provides the signal to the oscilloscope. It consists of another Tek custom IC U300 (155-0022-00) and its external components. This IC selects one, or mixes two, analog signals in response to logic inputs at pins 4 and 14. This vertical switch is located on CH 1 amp board.*

*The **trigger switch** is identical to the now described vertical signal switch, but is located on the CH 2 Amp board. This stage determines which input signal (CH 1 or CH 2) provides the trigger signal to the oscilloscope time base unit, according to the LEFT, VERT MODE or RIGHT push button. In this mode, the two amplifier are identical but can perform different functions.*



1

2

3

7A12 construction

The 7A12 has been already enough described. Note in these photos the modular approach and the overall good engineering.

Note also the attenuator boxes, very well silver plated.

Gold and silver, Tektronix didn't force to spare money...

❶ 7A12 left side view;
❷ 7A12 right side view;
❸ 7A12 top view

7A13 differential comparator

The 7A13 was a first generation plug-in, designed almost together with the former 7000-Series and was made until the 7000 series was retired in 1992.

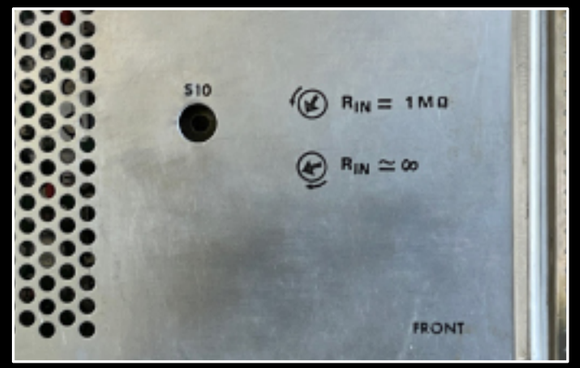
It is logically similar to the above described 7A22, with some relevant differences:

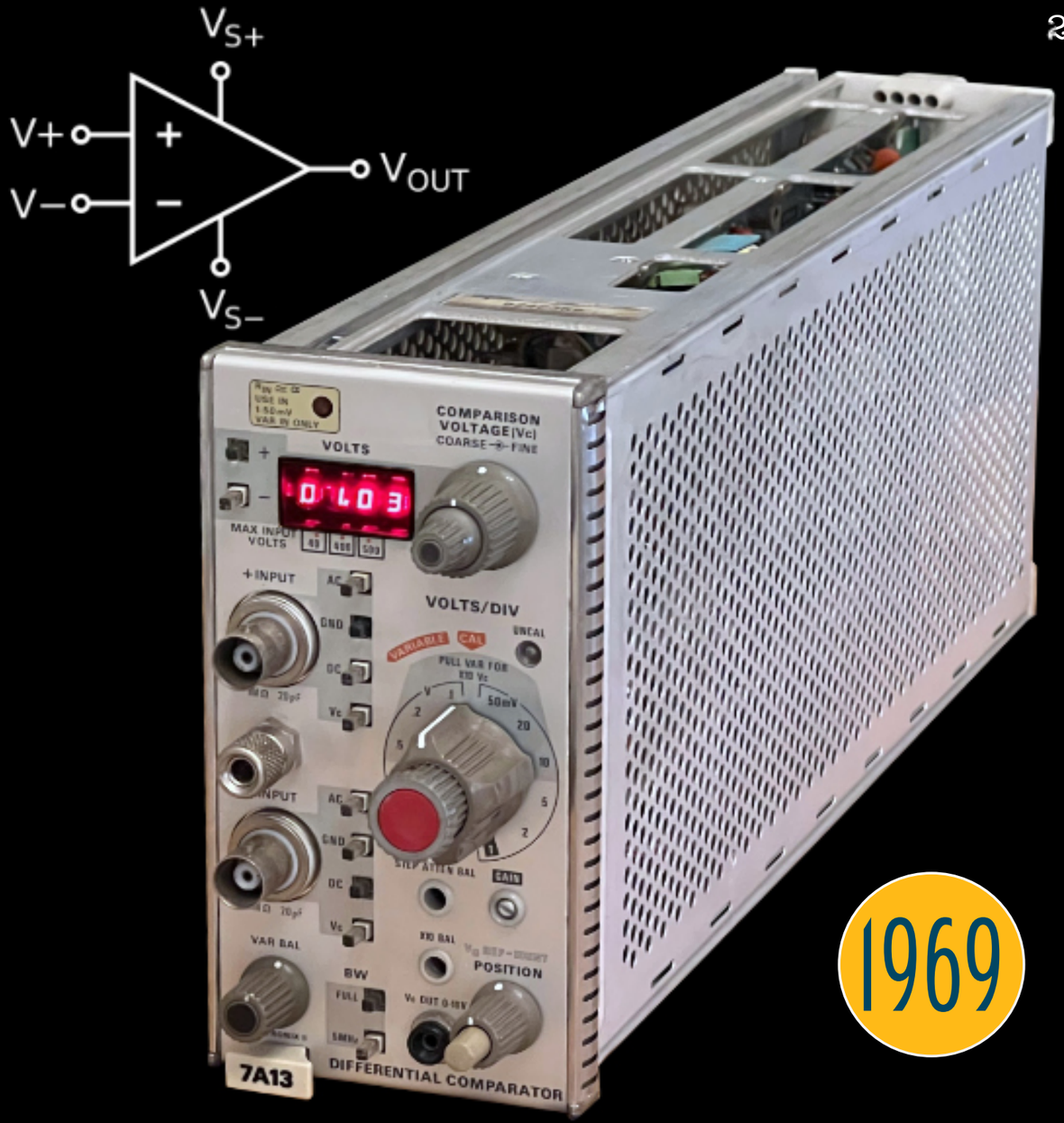
- *bandwidth: 100 MHz instead of 1MHz;*
- *sensitivity: the lower scale is 1mV/Div, while the 7A22 offers 10µV/Div;*
- *the higher CMRR was only 10,000 @1MHz compared to the 7A22 100,000.*

In differential mode, a ±10 V common mode signal can be present at the inputs without attenuation. Either input can be switched to the comparison voltage, an internal DC source that can be used for either channels, settable in 10,000 steps.

The adjustment of that DC source, was done originally with a 10-step switch and a 10-turn potentiometer, with an odometer type counter. In 1976, the counter was replaced by a digital circuit with a four digits, 7-segments, small display. A sign of the looming digital wave (see below).

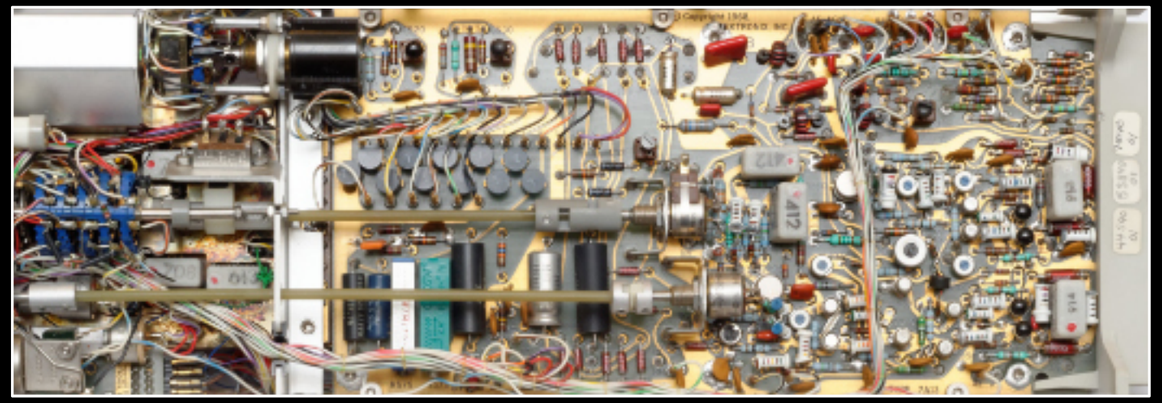
Note that the 1 mV/Div to 50 mV/Div ranges, the gate resistors can be disabled by the internal S10 switch (accessible from the left side of the plug-in, see the photo on the right), raising DC input impedance to "approximately infinite" (as indicated by a front panel lamp).





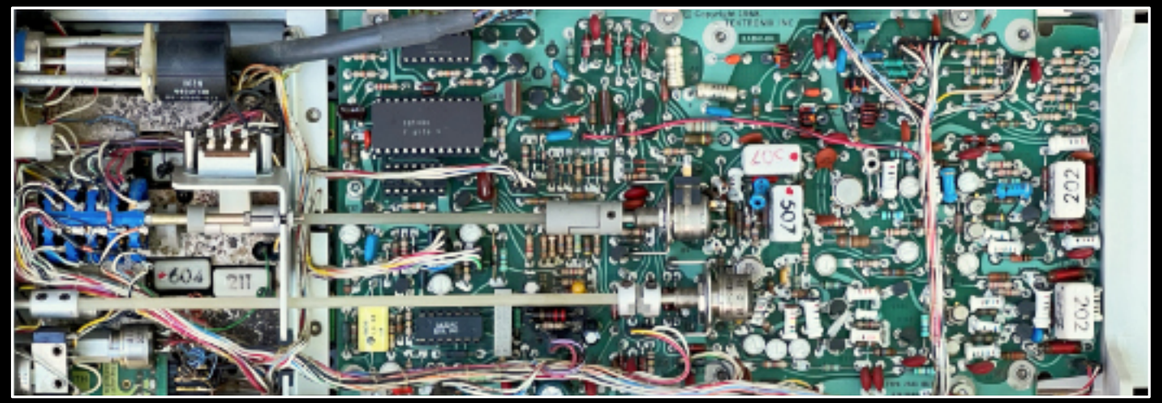
1969

1976, the digital tide



In 1976 the old mechanical counter was replaced by a modern 7-segment display. In the older version, the comparison voltage is generated from a precision zener supplied from either positive or negative 50 V rail, followed by a 10-step switched divider made of 0.1% resistors to select the first digit. For the lower three digits, a ten-turn potentiometer with a mechanical digital readout is used. The V/Div switch changes the decimal point on the readout, which is implemented through small light bulbs above the dial, with plastic light guides to make the decimal point appear between the digits. In contrast to the back-lit switches, the decimal point lamps are supplied from logic +5 V so they work also in mainframes without switch light supplies, e.g. the 76x3s.

In the newer version, the zener-derived reference voltage is always positive. A 10-turn pot for coarse selection combines with a single-turn pot for fine control. The resultant voltage is displayed on a 4-digit simplified DVM built around a Fairchild 3814 4½ digit DVM controller. For negative values of VC, an opamp polarity inverter circuit is switched in (from TekWiki).



The 1976 new electronics of the 7A13, that, from S/N B200000 up, replaced the original board (in the photo above). Note the 24-pin Fairchild 3814 4½ digit DVM controller that drove directly the multiplexed display. A true novelty at the time.

This beautiful photo (retouched from TekWiki) shows the wonderful gear that tied together a 10-step switch, a 10-turn potentiometer and an odometer type counter to allow the setting of the DC offset to the comparator in 10,000 steps.

In this detail: the digital version, just two potentiometers (coarse and fine) replaced all the gears.

The logic was simpler: no need for absolute linearity, the user could comfortably read the effective voltage on the 7-segment display.

7A13 circuit description

I report here the information that I would like I could have found in the 7A13 manual. I believe it can be useful if you are going to repair your 7A13. It is an overview of the attenuation system and of the many relays, that are likely your problem in most cases.

There are three main controls of the amplification factor: the input attenuator and two controls on the amplifier.

*The **input attenuator** has three levels of amplification: X1, X10 and X100 (see table), controlled by relays:*

- *K6 / K26 allow to pass the signal directly (X1) or attenuate the panel connector input signal X10;*
- *K7 / K27 allow to pass the signal from the previous attenuator directly (X1) or with a X10 reduction.*

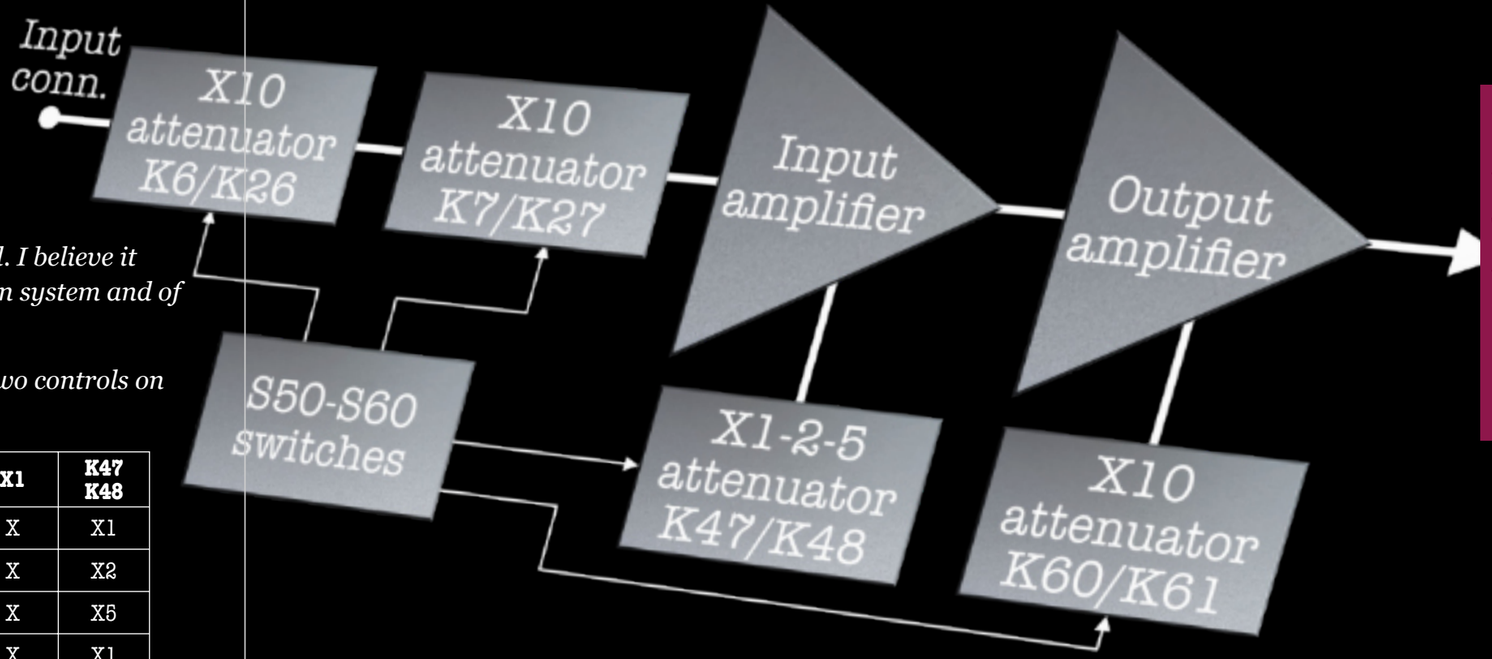
The X1 is obtained leaving the relays inactive.

Note that "X10" means 10 times attenuation (and not amplification); the maximum amplification is therefore X1. Note also that the wiring diagram is misleading because it indicates "X100" for the first attenuator. Both dividers work X10, when they work together, they obviously make 100.

	X10 K6/K26	X10 K7/K27	X1	K47 K48
1mV			X	X1
2mV			X	X2
5mV			X	X5
10mV			X	X1
20mV			X	X2
50mV			X	X5
0.1V		X		X1
0.2V		X		X2
0.5V		X		X5
1V	X	X		X1
2V	X	X		X2
5V	X	X		X5

*The **1-2-5 sequence** is instead made by K47 and K48, that operates on the input amplifier:*

- *K47 chooses X1 or X5;*
- *K48 chooses between X1 or X2, provided that K47 must be in X1.*



***Other relays**:*

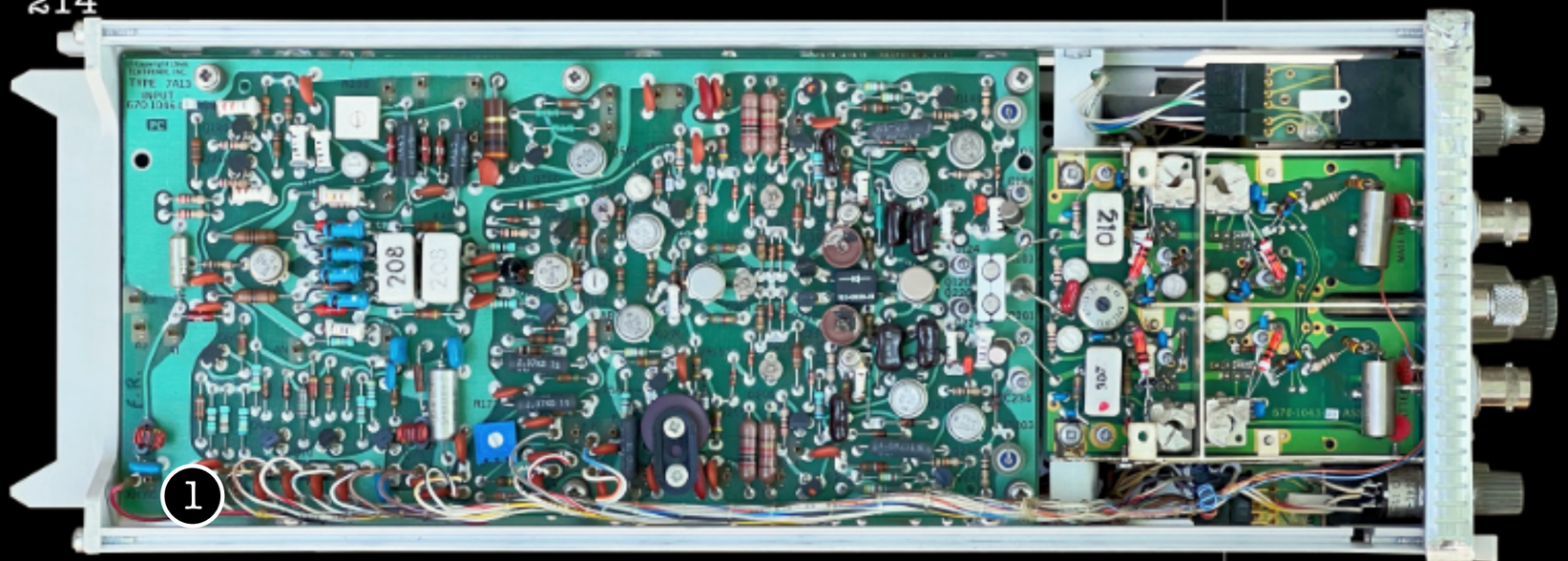
- *K10 / K30 only route Vc, i.e. the reference voltage, to the amplifier, when the relative button is pressed;*
- *K60/K61 operates on the output amplifier. Normally, it reduces the amplification X10. When the "PULL VAR FOR X10 Vc" command is activated, it is switched in X1 position and increase by ten the amplification factor; at the same time an extra X10 attenuator is inserted at the input (the one of the two that would not be used). Since there are only two input attenuators, this system can only be used in the 6 middle positions (.5V to 10mV). All that has the purpose to extend by 10 times the effect of Vc (and also the input rank of the DC component at the input).*
- *K480 / K490 are used for bandwidth reduction (BW 5MHz switch on the front panel).*

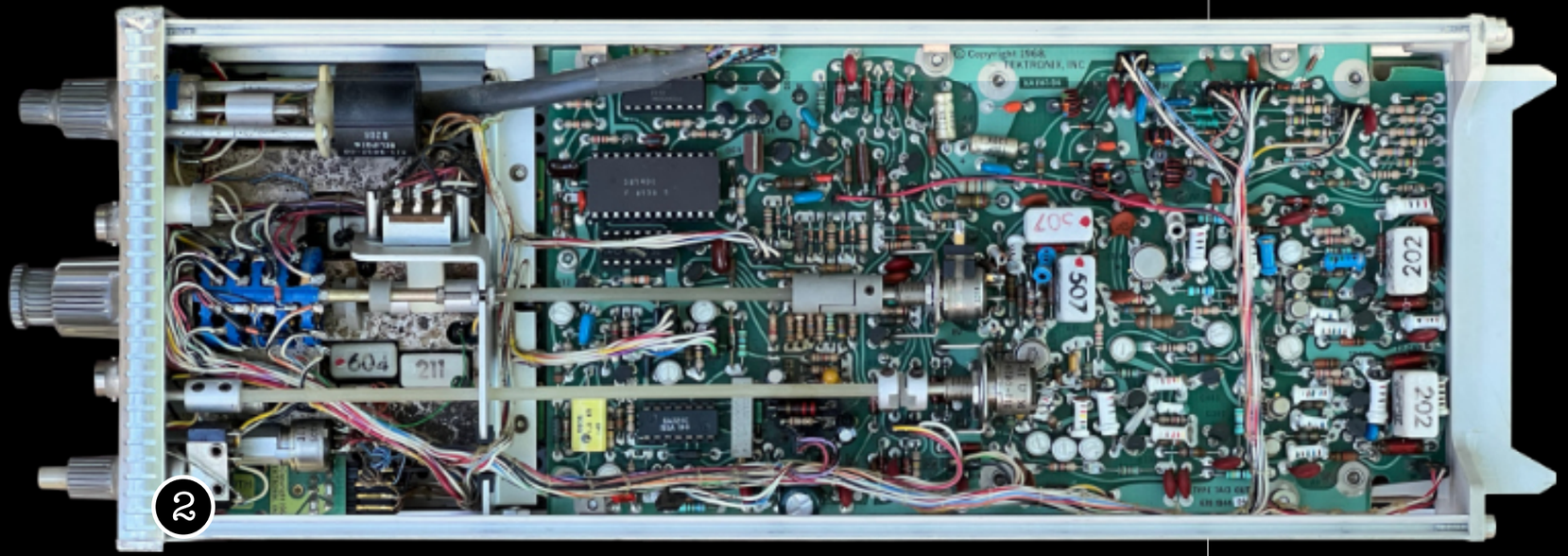
In the last section of this book, you can find some suggestions about the relays reparation ("Relays reparation").

7A13 construction

The Tektronix 7A18 has the typical structure of the original 7000-Series plug-ins. To be noted the use of a traditional switch, instead of a Tektronix cam switch, and the presence of many Tektronix relays, today sometimes critic.

❶ 7A13 left side view; ❷ 7A13 right side view; ❸ 7A13 top view
❹ 7A13 front view (mechanical counter, pre-1976)
❺ 7A13 front view (digital display, 1976)





7A18 nice & simple [216]

75 MHz dual-trace vertical plug-in

The Tektronix 7A18 is a general-purpose 75 MHz dual-trace vertical plug-in. It is one of the simplest plug-ins of the 7000-Series and was, maybe, one of the most popular vertical amplifier for the 7000-Series. It is possible that most wanted to have a 100 MHz scope, like 7603, "for the future", but that 75MHz were considered however enough. The price difference with the bigger brother 200MHz, 7A26 was about twice (615$ vs. 1,150 in 1976, roughly 3,000 vs. 6,000 today, not peanuts indeed and furthermore probably duplicated for two vertical plug-ins), and the 7A26 had furthermore a 100MHz surplus, not usable with the 76xx-Series.

Where is the gain control?

I admit that, at beginning, I didn't understand a fundamental point: all the 7000 vertical amplifiers have not an absolute calibration, and imagined faults not really present. Perhaps it was not easy to ensure that all the mainframes had the same amplification factor. So Tektronix provided a way to quickly adjust the gain, considering that not a lab alignment but a normal routine operation. Some plug-ins have a screw on the front panel to do that. But where are that screws on the 7A18 (and 7A26 as well)? Again Tek concentrated more and more function in a single knob. If you press the black topped knob VARIABLE, the knob gets out and you can adjust the gain according your will. This gain is obviously uncalibrated and the operation is very intuitive. But I did not understood that that knob has another function: it can adjust the overall gain of the plug-in, by pressing it and turning it with a screwdriver (see the drawing). Simple and effective!

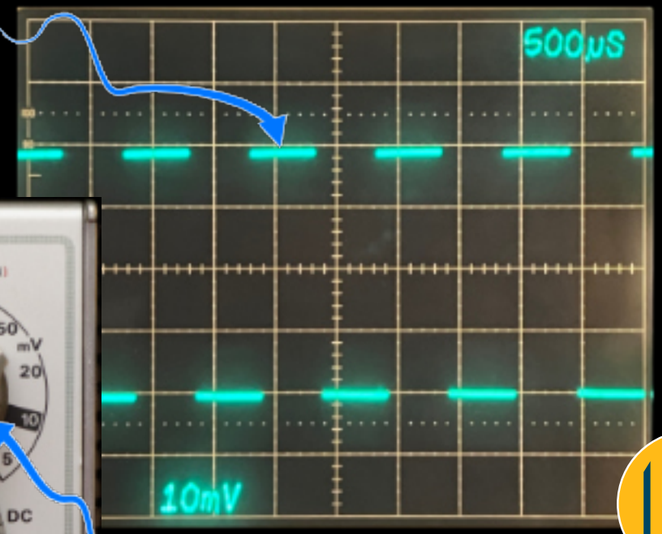
Repairs

TekWiki says that...

> "The pins of the attenuator modules are connected to conductive traces on the ceramic substrate inside by low-temperature soldering, which can go bad. Re-seating the module can temporarily restore the internal contact but will usually not fix the problem permanently. Repair is possible by opening the click-locked lid and carefully resoldering".

Until now, I had a lot of problems with "noisy" controls, but all of them flew away just with a good cleaning (see "Switches and pushbuttons"). Like other plug-ins, also the 7A18 has an high risk to see the Tantalum capacitors to bust. Personally I am too lazy (or prudent) and avoid unnecessary interventions, but can be a good idea to replace them with modern ones.

You can use the oscilloscope internal calibrator 400mV output with the 10:1 probe and obtain exactly four divisions on the screen

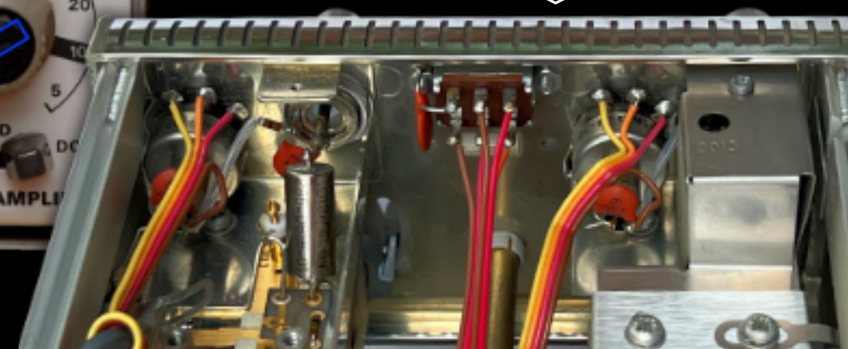


1971

GAIN knobs

Press the knob with a screwdriver and rotate until the trace fit with the calibration value (in 10mV VOLT/DIV position)

Not so easy... in spite of appearances, disassembling the 7A18 front panel is definitely not simple. My suggestion is doing it only when absolutely necessary.



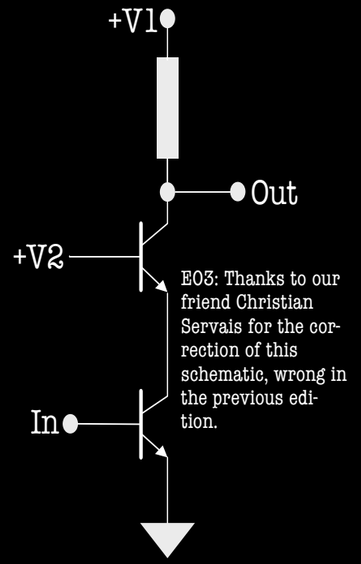
The cascode amplifier

*The 7A18 circuit is reasonably simple and was for me the opportunity to understand the **cascode amplifier**, which I have never had the opportunity to deal with.*

Cascode, what does it means?

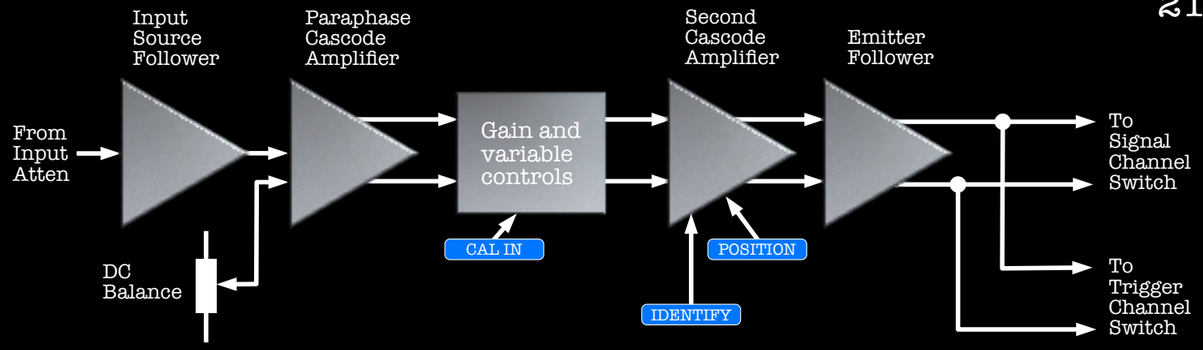
*My first curiosity was its **name**, and that is a curiosity that I have been carrying for a lifetime. In 1956, my father bought one of the first televisions, brand "Admiral", and I remember that it had written in the front panel "advanced cascode"; its meaning remained a mystery for me.*

*Sixty six years later, I decided it was time to understand this word. My English is not too good, and, initially, I thought it was some slang form of "cascade". But, thanks to Wikipedia, I learnt that the name **cascode** was coined in an article written by Frederick Vinton Hunt and Roger Wayne Hickman in 1939, in a discussion on the application of voltage stabilizers. They proposed a cascade of two triodes (the first one with a common cathode setup, the second one with a common grid) as a replacement for a pentode, and so the name may be assumed to be an abbreviation of "casc(aded triode amplifier having characteristics similar to, but less noisy than, a single pent)ode".*


+V1
Out
+V2
In
E03: Thanks to our friend Christian Servais for the correction of this schematic, wrong in the previous edition.

Cascode, what does it do?

We have so already said what a cascode amplifier is. Here above, you can see its basic circuit. Although simple, it offers many advantages, such as high gain, high bandwidth, high slew rate, high stability, and high input impedance, with a very low parts count, but requires a relatively high supply voltage.

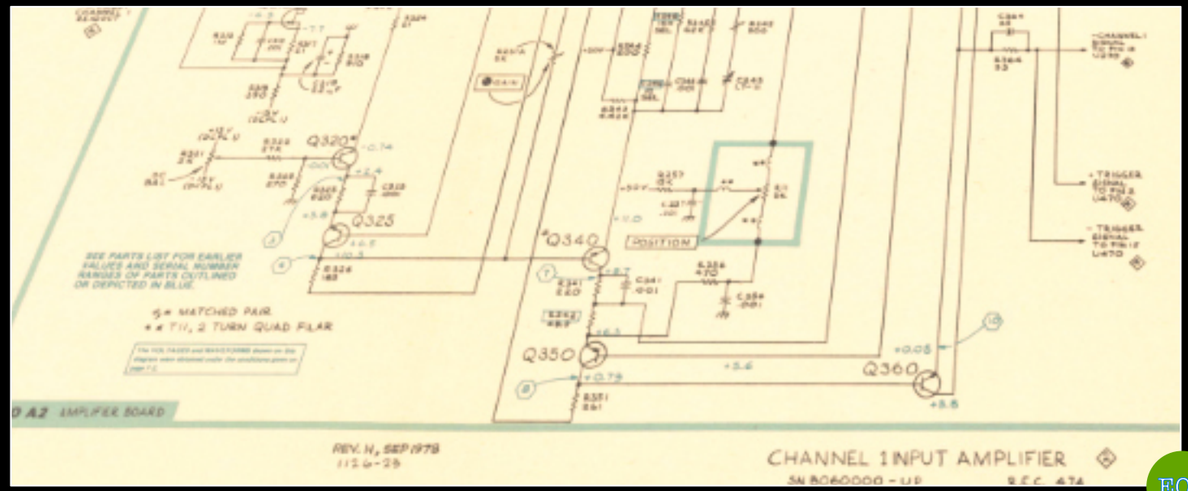


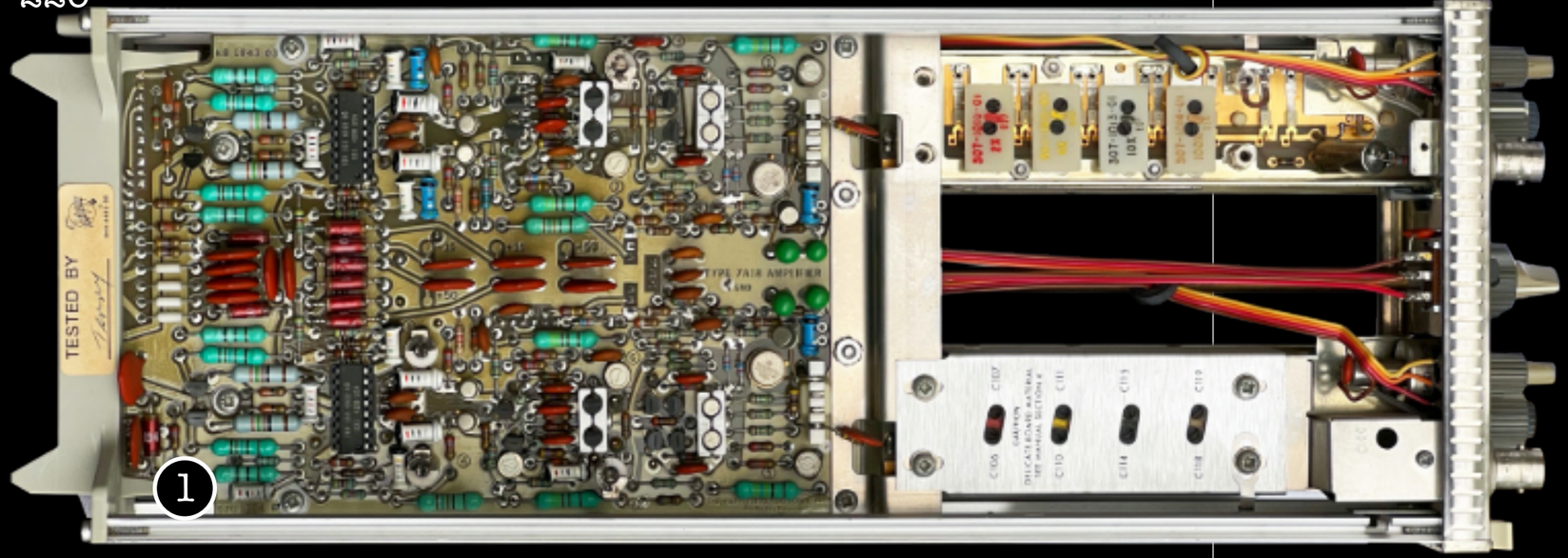
The 7A18 circuit

As you can see from the above block diagram, the 7A18 uses a FET input source follower stage, followed by two differential cascode stages with bipolar transistor and a final emitter follower. The circuit, here reported from the manual, is very well optimized and at first sight looks simpler than really it is.

Calibration

Besides the input attenuators, the calibration is straightforward and requires only few adjustments. For the input attenuators, see the suggestions reported fin the "Restoring Tek scopes" at the end of this book.





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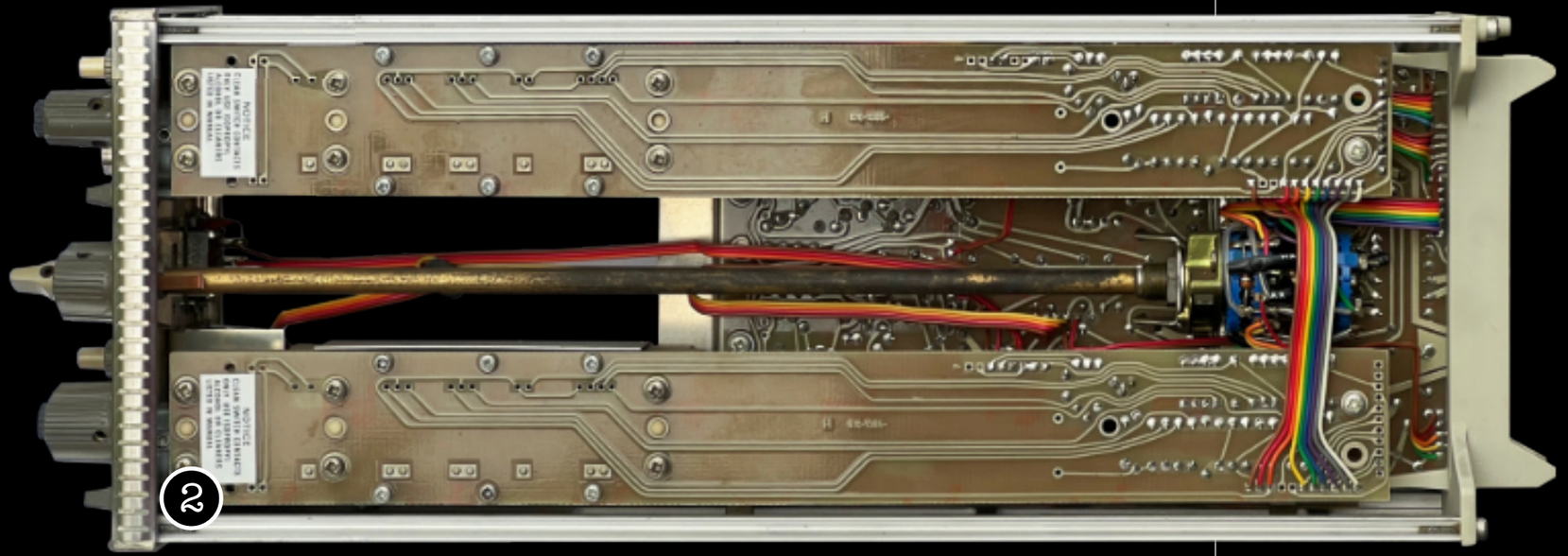


2

3

7A18 construction

The 7A18 structure is apparently very simple but not very practical when you need to work on it. It seems that every part is in some way blocked by something else, that you have to beforehand disassemble, and so on in an iterative way.

As mentioned, the attenuator is the same used on other models, and can be calibrated with a procedure described talking about the 7A26.

As usual, the ubiquitous Tantalum capacitors, that carry the problems already described, and the semiconductor sockets, very useful during fault investigation.

❶ 7A18 left side view; ❷ 7A18 right side view; ❸ 7A18 top view

7A22 differential amplifier

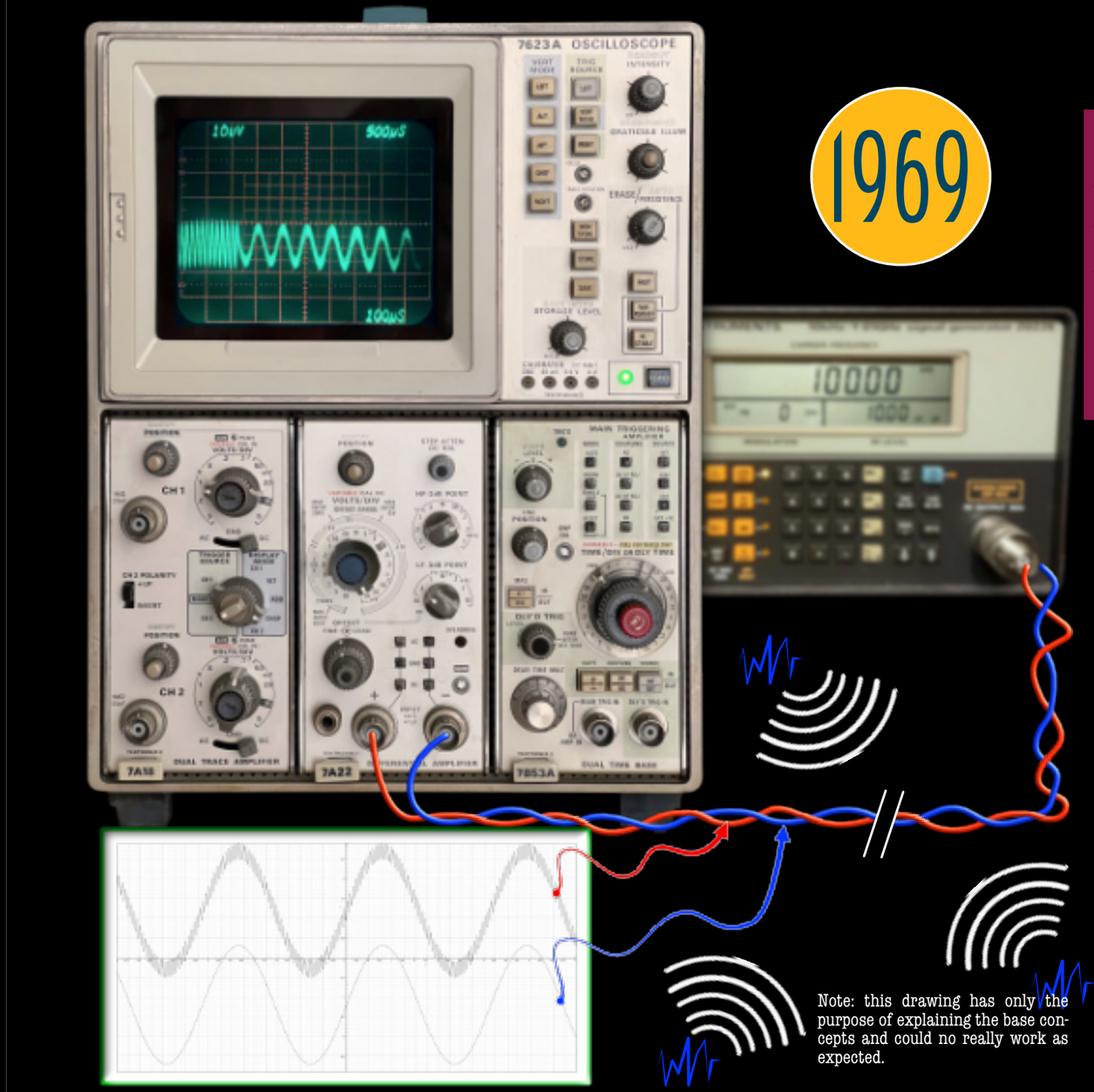
The Tektronix 7A22 is a very sensitive, single channel, differential vertical amplifier for the 7000-Series mainframes produced from about 1969 to 1991, for signals up to 1MHz. A differential amplifier is a type of electronic amplifier that amplifies the difference between two input voltages, but suppresses any voltage common to the two inputs. Its output is ideally proportional to the difference between the two input voltages.

A differential amplifier is very useful when you need to analyze low amplitude voltages with superimposed high levels of noise. An example could be a long RS-485 line in an industrial environment. A strong electrical noise is coupled to both wires of the RS-485 line. If you look at each of them with a common oscilloscope, you can only see the noise, but the noise is almost the same for each conductor. If you connect each conductor to one of the two inputs of the 7A22, you will be able to see an incredibly clean trace of the signal.

But how much noise can the 7A22 cancel? We express this capability with the CMRR, the ability of the device to reject common-mode signals, i.e. those that appear simultaneously and in-phase on both inputs. An ideal differential amplifier would have infinite CMRR. The 7A22 offers a CMRR of 100,000:1 (or 100dB).

As we said, the 7A22's input sensitivity is very high and arrives down to 10 µV/Div. So, the 7A22 is ideally suited for applications that include audio, biological signals, sensors etc.

Bandwidth is 1 MHz, the upper 3 dB limit can be reduced in ×3 steps down to 100 Hz (to eliminate noise, inter alia), and the lower bandwidth can be raised in ×10 steps from 0.1 Hz to 10 kHz. A separate control optionally supplies an internal DC voltage to offset the DC signal component. Even in the most sensitive ranges (10 µV/Div to 10 mV/Div), common-mode voltage can be ±10 V. Input resistance is 1 MΩ, but for high source resistance DC coupled measurements, one can disconnect the internal gate return resistors of the input FETs, at the disadvantage of disabling the 20 mV/div and higher ranges.

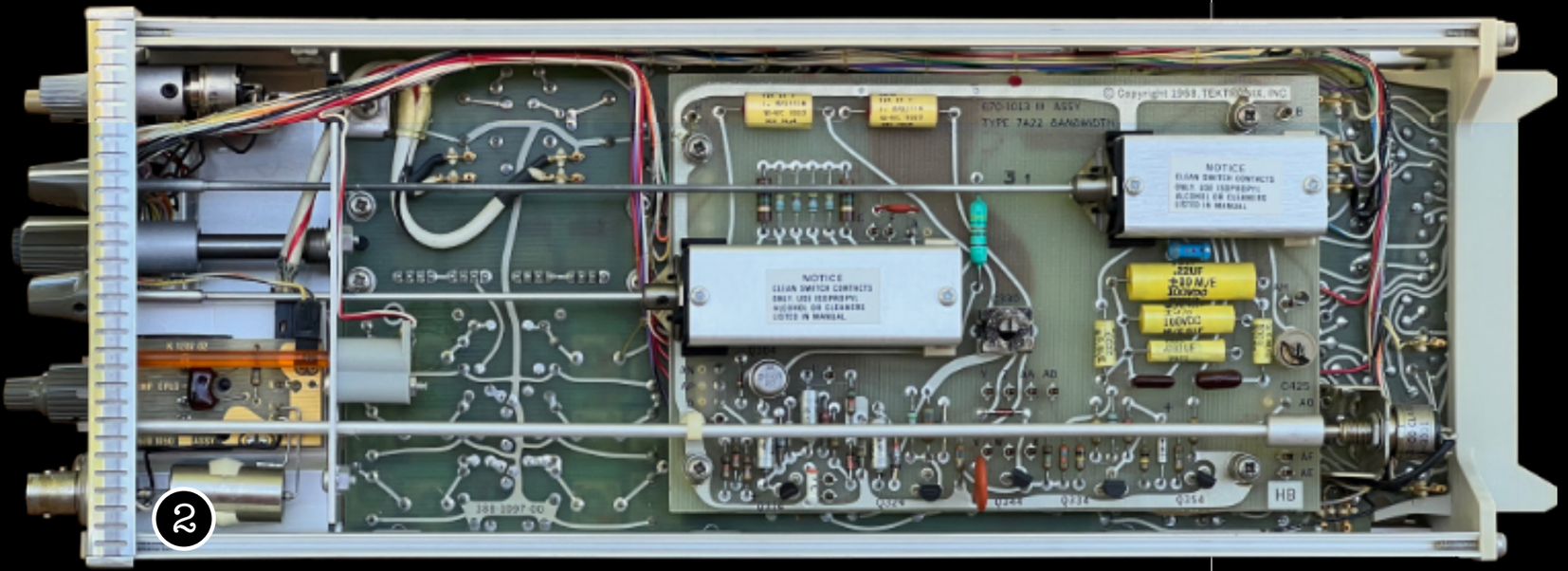


7A22 construction

The construction is typical of the earlier 7000-Series devices. Note the four Tektronix cam switches, easy to be accessed for maintenance and cleaning.

❶ 7A22 left side view; ❷ 7A22 right side view; ❸ 7A22 top view; ❹ 7A22 front view.

1



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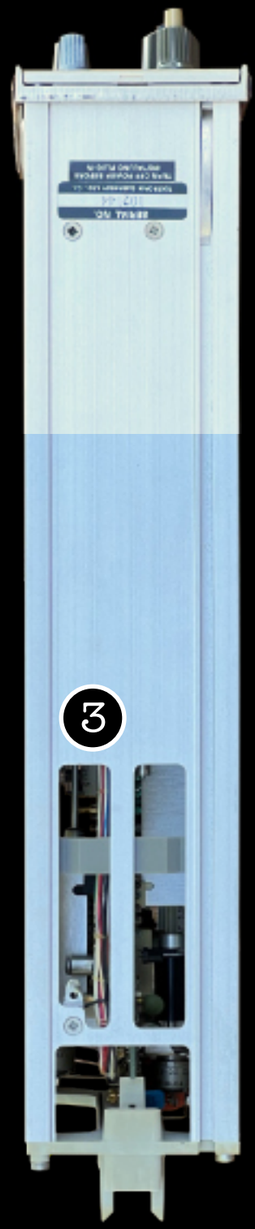


3

FUSES: the inputs are diode-clamped to fixed voltages of approximately + 16.5 volts and/or –16.5 volts. If the maximum input voltage rating in the 10 µV to 10 mV range of the VOLTS/DIV switch is exceeded, damage to the signal source is possible. If the signal source can supply more than 1/16 A of current, the input protective fuse(s) shown here in the photo ❶ will open, as I DIRECTLY experienced. An open input fuse is indicated by the lighting of the INPUT OVERDRIVE indicator with with the input coupling switches set to GND. Two fuses are supplied as spare.

A possible fuse is Mouser P/N 576-0312.062MXP.

4

7A22 other details

The 7A22 had to deal with very low amplitude signals, so the effect of the side covers was definitely not negligible. They had to be kept in place during calibration, and thus tho holes for each trimmer. On the right, the nice connection system used for the wires, avoiding soldering.

7A26, the golden boy

200 MHz dual-trace vertical plug-in

The 7A26 was the most successful 7000-Series plug-ins, with over 120,000 units produced. It was designed by Tom Rousseau, who was the designer also of the 7A15A, 7A16A, 7A18, 7A24, 7A26, 7854 and other important Tektronix products. On the occasion of the production of the 7A26 S/N B100100 (the 100,000th), a special 7A26 with gold-plated panel was presented to him by Tektronix, as reported by vintagetek.org, where I took the photo on the right..

The 7A26 is apparently very similar to the 7A18, from which it can be recognized by the presence of the BW switch. Also the construction is similar, but the circuit is much more complex, although the extensive use of the Tek-made differential amplifier ICs 155-0078-xx. To be noted, that the 7A26 does not use the ±50V supplies provided by the mainframe.

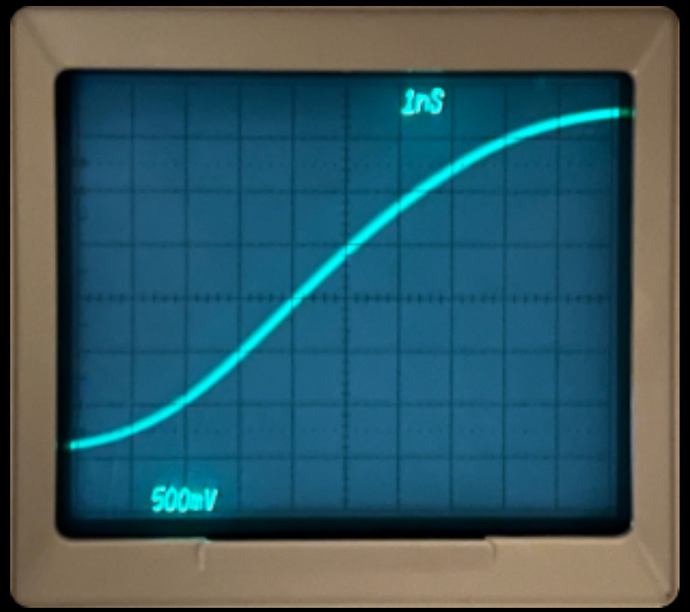
Calibrating 7A26 is much more difficult that 7A18, for the large number of trimmers to be tuned. But the attenuator calibration is similar for many of the 7000-Series vertical amplifiers. You can find suggestions to perform it in the section "Restoring Tektronix oscilloscopes" at the end of this book.

1974

Gold also in production units

Look at the picture on the right: there is gold everywhere! Today, if an engineer proposed something like that to me, I could ask "did you become mad? Who is going to pay for all that gold?". But at that time things were probably different...

The quality of Tektronix products was incredible indeed (and surely is still today); that is one of the reasons that allowed the 7000-Series to to cross the barriers of time.



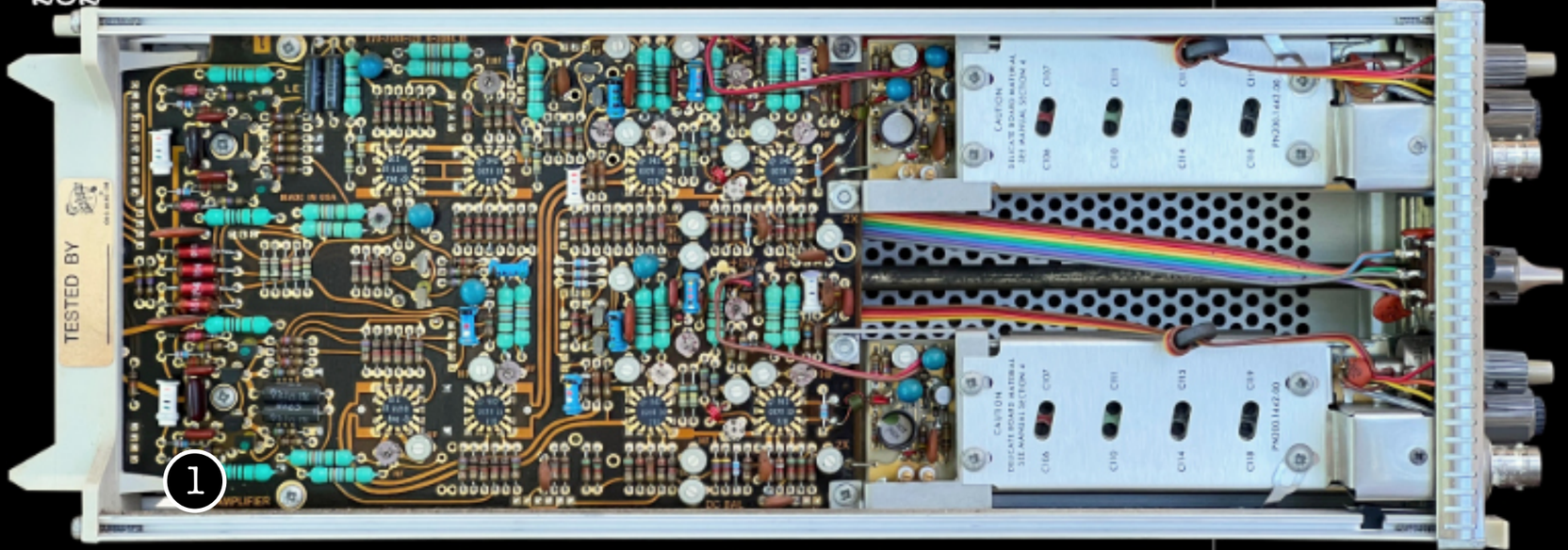
A photo taken with my 7904, using a 7A26 and the 7B85 time base. To see a picture like this at 1ns/div was not easy with the oscilloscopes that most of us could afford of the time.

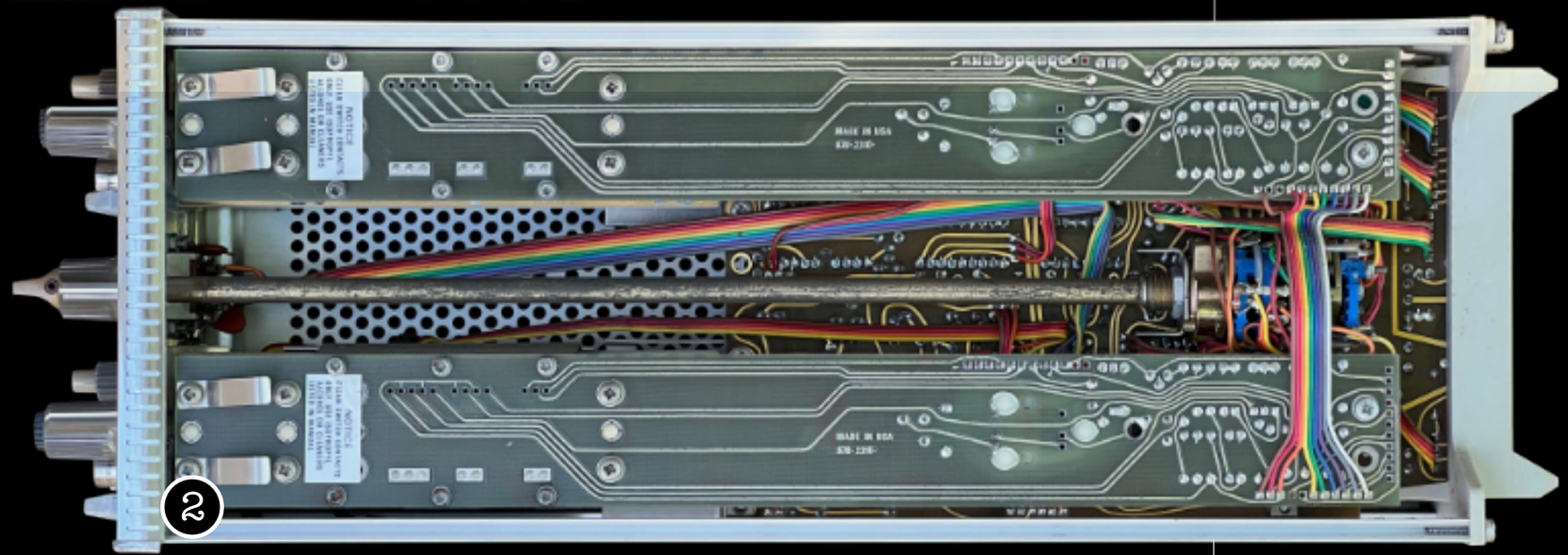
1974

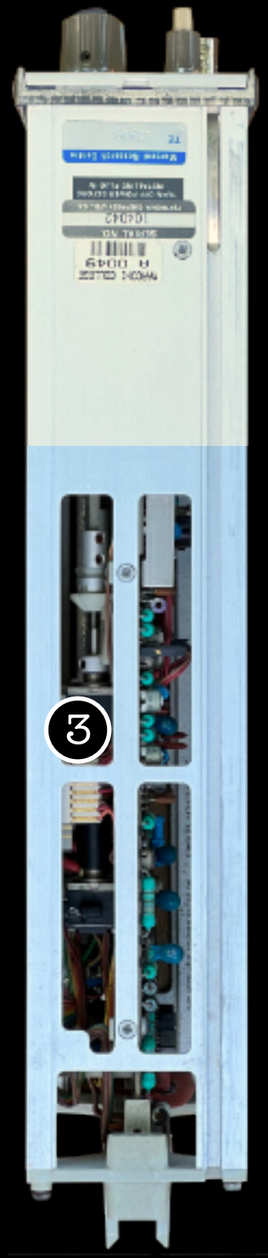
7A26 construction

The Tektronix 7A26 construction is very similar to 7A18.

❶ 7A26 left side view; ❷ 7A26 right side view; ❸ 7A26 top view; ❹ 7A26 front view







1974

7A24, fastest dual

400 MHz dual-trace vertical plug-in

The Tektronix 7A24 is a 400 MHz dual-channel vertical plug-in for 7000-Series scopes. I received two of them together with the 7854, confirming what TekWiki reports, that the 7A24 would typically have been used in 7834, 7844 or 7854 mainframes.

TekWiki reports that a single-channel version was planned as the 7A25, but it didn't reach the production stage.

The fastest multi-channel

The 7A24 was the fastest multi-channel plug-in of the 7000-Series, but the 400 MHz could be reached only with the subsequent 7104. The bandwidth limit was 350 MHz with 79xx, and 300 MHz with the 78xxs.

Channel inputs

The 7A24 channel inputs present a 50 Ω impedance, with 5 Vrms maximum (0.5 W); however it was not damaged below 10 V (2 W). A fuse in the input of each channel protects the 7A24 from damage due to excessive signal voltages. The condition of blown fuse can be detected by when no waveform can be displayed, but the POSITION control will move the trace on the CRT. The fuse replacement was considered an operation to be performed by qualified service.

The recommended probes were the P6056 and P6057. I discovered with surprise that, unlike most other plug-ins, the 7A24 does not offer AC input coupling.

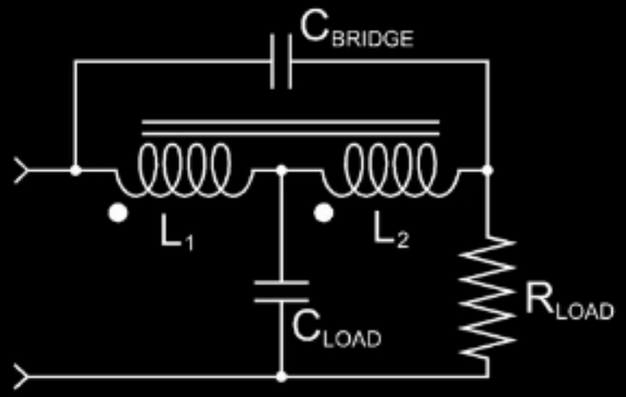
7A24

400 MHz dual-trace vertical plug-in

The circuit

The 7A24's input attenuators are similar to that in the 7A19, using replaceable ceramic attenuator modules held to the switching PCB using steel springs.

The amplifier is built using the Tek-made differential amplifier 155-0078-xx (four units per channel in early, five in late versions; various grades). In the 5 mV/Div range only, the amplifier gain is doubled electronically. The signal trace layout on the PCB is designed to provide T-coil peaking.

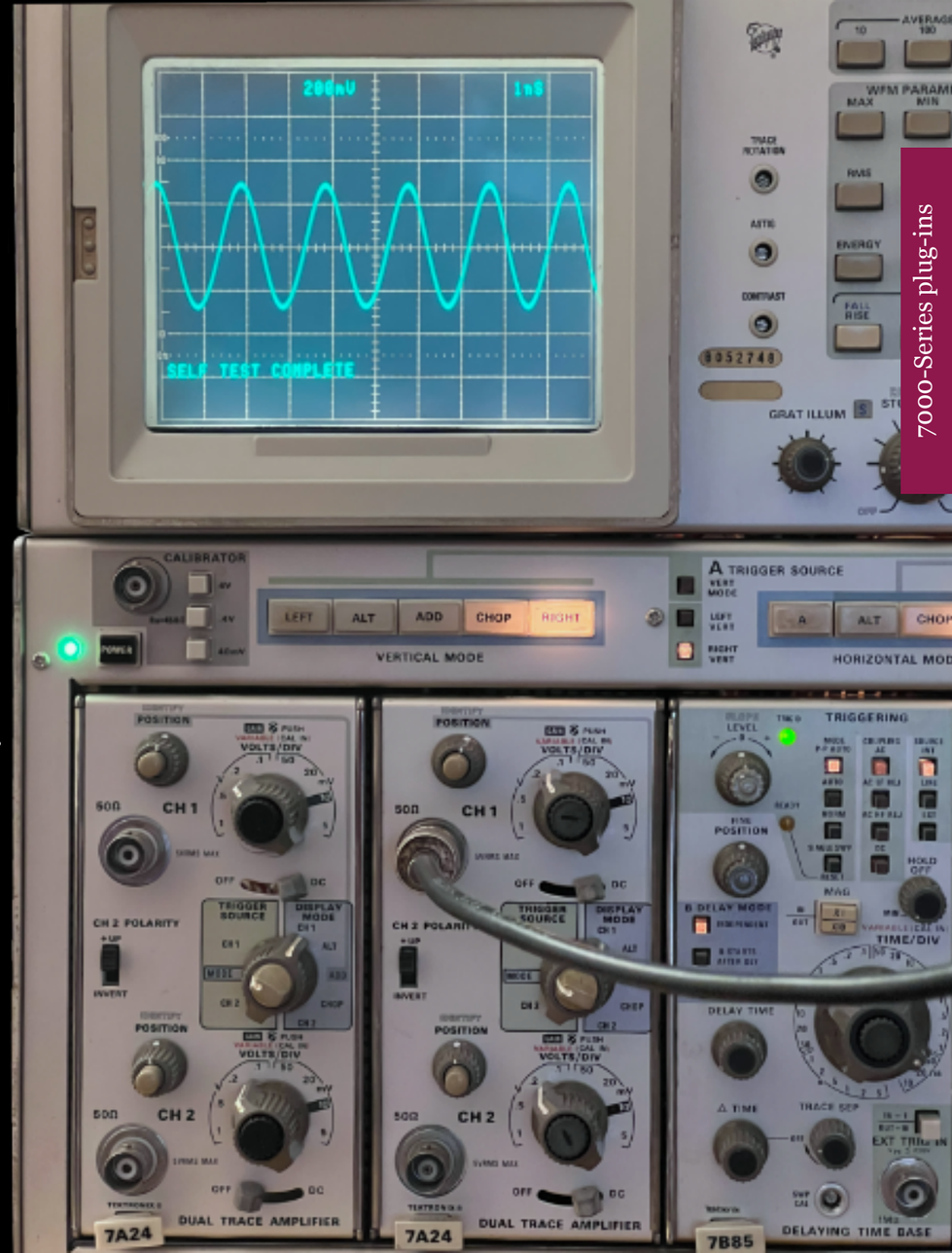


A T-coil (see drawing) is a special form of an inductive peaking circuit that will extend an amplifier's bandwidth and speed up the output signal rise-time. The circuit uses a coupled inductor and a small bridging capacitor. A T-coil can double the bandwidth of an amplifier. You can think of the inductor as steering input current into the capacitive part of the load, so it charges up more rapidly. The small bridging capacitor ensures that the input impedance of the T-coil is constant and resistive (from https://www.electronicdesign.com, where you can read the whole story).

The 7A24 does not use the ±50 V supplies provided by the mainframe.

1974

E03



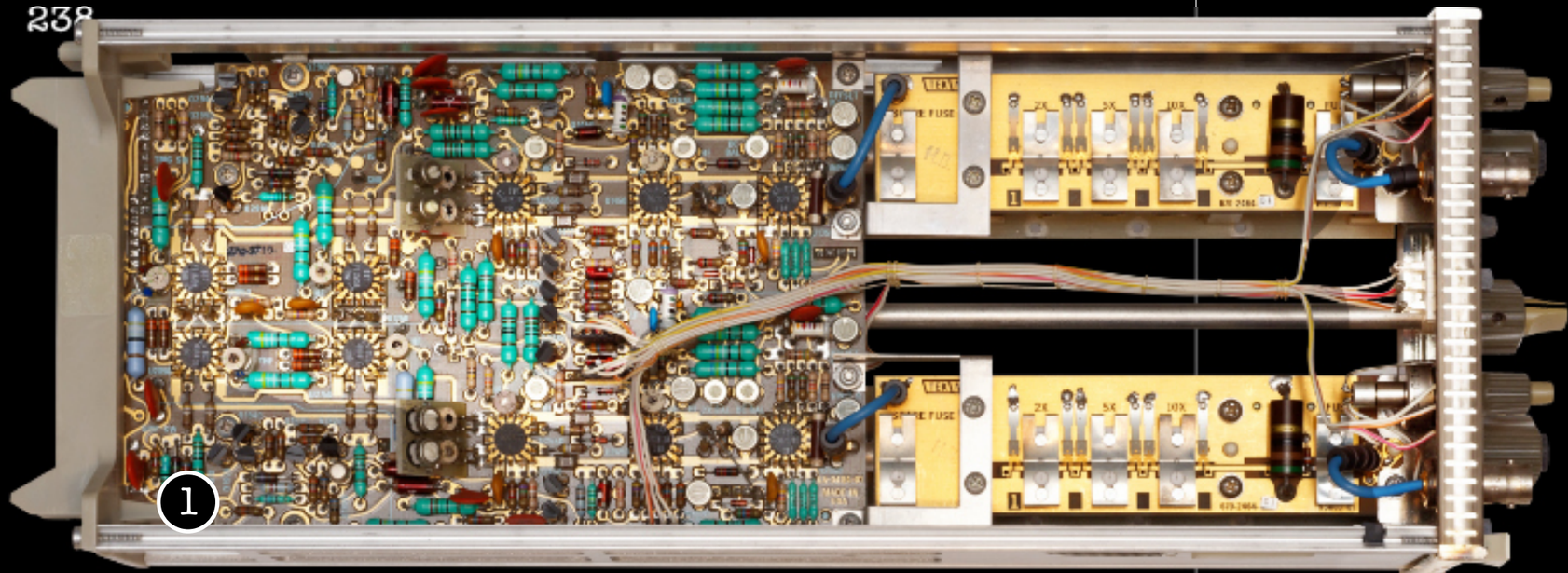
In this picture, you can see the 7854 mainframe with two 7A24, easily recognizable for the input switch without the AC position.

The 7A24 active in the picture arrived home not working. The symptoms where those of the burn input fuse: the track could be moved with the POSITION control, but no signal was shown. Really, it had only dirty attenuator contacts, as most of the plug-ins that have been re-mained sleepy for years.

Its performances are still very good: 310 MHz on the 78xx (-3dB). In the picture here, the input signal is at 550 MHz. The amplitude is reduced to about 50%, but the display is still well triggered, stable and bright (note the 1nS/div, due to the horizontal x10 expander).

7A24 construction

❶ 7A24 left side view. The construction resembles other 7000 plug-ins, like 7A18 and 7A26. Very different the attenuator. Note the connector on both sides of it, very practical when you need to disassemble the unit to clean the contacts. ❷ 7A24 right side view; ❸ 7A24 top view; ❹ 7A24 detail; note the 155-0078-01, a Tektronix custom IC very used, not only in the 7000-Series. This version, relatively recent, uses five of them.



7000-Series time bases

After having reviewed some vertical amplifier, let's now examine some of the horizontal plug-ins, used to produce the trace horizontal scan on the CRT.

According to TekWiki, these were the most common timebases:

- *7B50/7B51 (1969): triggering up to 100MHz (down to 5ns/div);*
- *7B70/7B71 (1969): triggering up to 200MHz (down to 2ns/div);*
- *7B53A (1973): triggering up to 100MHz (down to 5ns/div);*
- *7B80/7B85 (1976): triggering up to 400MHz (down to 1ns/div);*
- *7B92A (1971): triggering up to 500MHz (down to 0,5ns/div);*
- *7B10/7B15 (1978): triggering up to 1GHz (down to 0,2ns/div).*

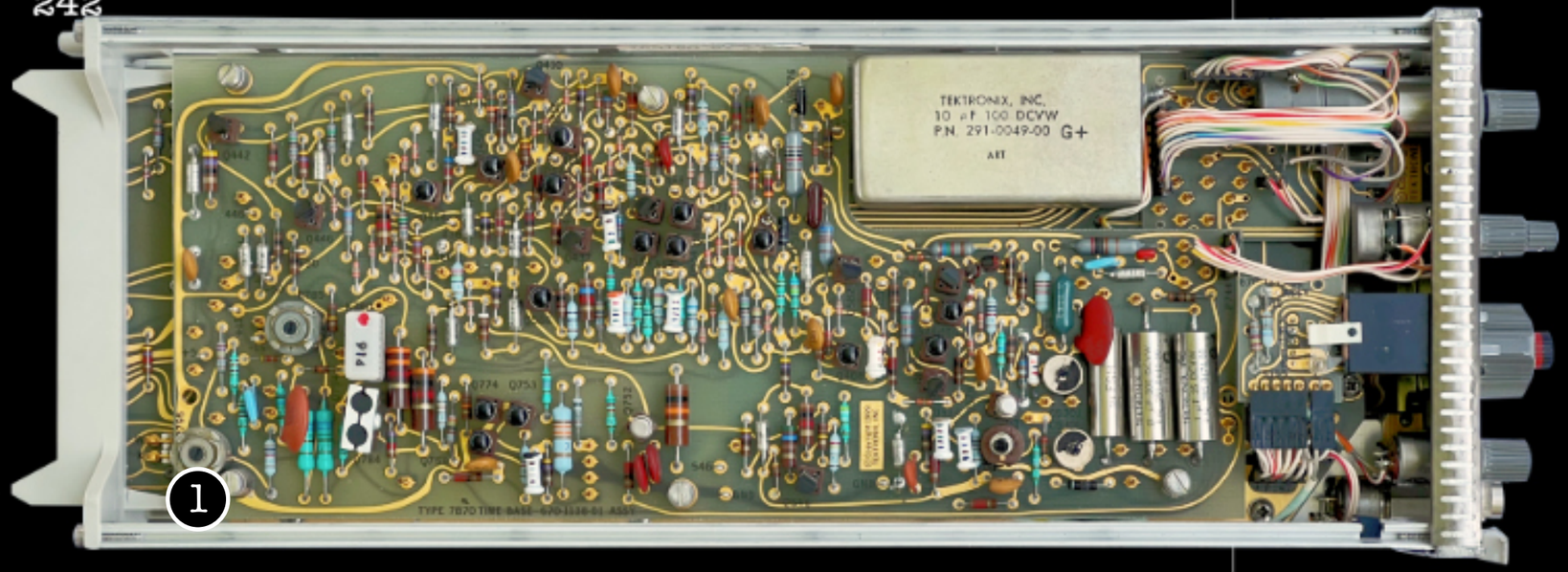
I think that the first 7000-Series oscilloscopes were mainly of the 4-bays type. The dual timebase 7B53A had still to arrive, so most of the configurations possibly included two separate plug-ins for the main and the delaying timebases.

The successful 7B53A was however limited to trigger up to 100MHz and down to 50ns/div (5 with the x10 expander). Who bought a 7704 or, later, a 7904 had the right to ask for something better. So, the dual plug-in solution (main + delaying) for the timebase remained a valid solution for high performances oscilloscopes, even if the 7B92 500MHz dual time base had become available.

In the following pages, we are going to shortly review some of the above listed timebases.

7B70 time base

Let's start our review with the relatively short-lived 7B70, a 200 MHz time-base plug-in for 7000-Series scopes. It has no delay function. For delayed-sweep applications, the 7B70 was operated in conjunction with the model 7B71 delaying timebase. The couple was primarily intended for the 7704 mainframe and was superseded by the 7B85/7B80 pair (400 MHz) in 1976, that we will describe more deeply. The 7B70 was entirely based on discrete components, without any custom IC, and used four relays.



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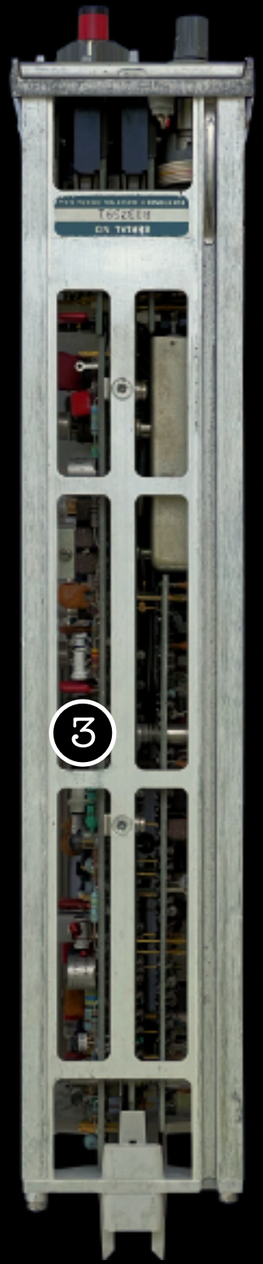


3

4

1. 7B70 left side view
2. 7B70 right side view
3. 7B70 top view
4. 7B70 front view.

1969

7B53A 100 MHz dual time base

The 7B53A is a 100 MHz dual time base introduced in 1973 and is one of the best guessed components of the 7000-Series. Discontinued in 1992 together with all the 7000-Series, it remained in production with no major modifications for almost twenty years. I can only suppose that the 7B53 had been conceived together with the 7603 oscilloscope. The original 7704, base of the 7000-Series, had four slots and two time bases, normal and delayed. As the idea of a smaller 7000 scope arose, the problem was "how to renounce to a plug-in slot?". From that the 7B53, whose one of the most peculiar features was the sweep mode selection integrated into the Time/Div switch, that gave someway a touch of magic to the waveforms investigation.

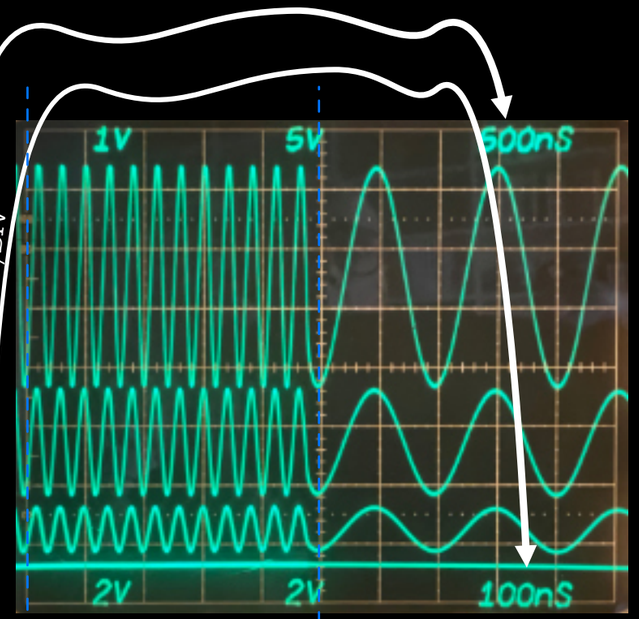
The dual time base concept was however not new and was present also in the previous generation tube oscilloscopes, like the 545 that I owned in a previous life. In simple analog scopes, the event you are investigating must begin and end within the desired time/div setting (e.g., 1µs/div) times the grid size, typically 10; something like a window that starts at the trigger event, ten division long.

The dual time base allows us to move that window forward in the time, as shown in the drawing nearby. For example, to investigate with 1µs/div resolution a waveform after one second from the trigger event, you can use the main time base as a timer, together with the DELAY TIME MULT knob, to continuously set the delay time from the value set on the TIME DIV or DELAY TIME knob (I call it TDoDT), to ten time its value. If the TDoDT knob is set to 1µs/div, you can adjust the delay with the DELAY TIME MULT knob from 0 to 10µs. The delayed sweep can start immediately at the end of this delay or can require a further trigger event (DLY'D TRIG knob).

The magic of the 7B53A integrated command is that with a single knob you can set the delay with the TDoDT knob and the scan speed, pulling and rotating again the same knob. The process is simple: set the time base to see all the period of time you want to explore, pull the knob, a part of the trace will be highlighted. Now adjust the knob (and the DELAY TIME MULT) to highlight the part you want to examine, press it again and then and pull the little CAL red knob. The enhanced part will be expanded and can be moved forth and back with the DELAY TIME MULT (see also the picture). A real zoom on the details...today we can do a lot better, but at that time it was simply wonderful. And that saving a plug-in slot...

The type N (7B53AN), is, as usual, the version with no readout system.

TIME/DIV or **DLY TIME** knob (briefly "TDoDT")



This delay is equal to:

DLY TIME x **DELAY TIME MULT**

1973

Note that the label of this button has been recreated as explained in this book. For optimum results, all the buttons should be remade or the difference in the color is too clear respect to the yellowed ones.

DLY'D TRIG knob

Delayed sweep starts after the delay time if set to detent position (RUNS AFTER DLY TIME) or set delayed trigger LEVEL

DELAY TIME MULT knob

Moves continuously this line forth and back from DLY TIME to DLY TIME x 10

The TIME DELAY MULT knob allows to read near two decimals of multiply factor to be applied to DLY TIME. In this case, the reading is 5.10 times.

The circuit. *The 7B53A circuit is complex indeed, but with the help of the manual can be in some way decoded and followed. The plug-in is roughly composed by 750 electronic components (plus about 250 mechanical parts), perhaps much more than an entire modern oscilloscope. As many as 11 integrated circuits managed the most important functions. Besides some logic ECL ICs and transistor arrays, its worth to mention:*

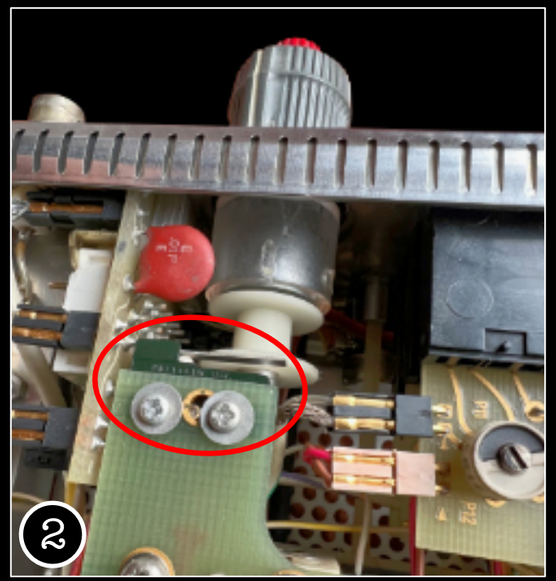
- *155-0049-00 (U520) with the sweep control logic: bright baseline auto circuit, single sweep circuit and hold-off circuit with terminals for the single sweep reset ready light, triggered light, auto timing, hold off timing, and two pins for new general logic (i.e., lockout and mainframe delay mode control);*
- *155-0042-03 (U580, U650), a gated Miller Integrator with a delay pick-off comparator. It is the main motor for the sawtooth sweep voltage and also also the heart of the linear-precise TIME DELAY MULT control knob.*

Note that the 7B53A has been built with two different trigger control board: until S/N B209999 there were 6 ECL ICs, that were substituted from S/N B210000 up, with two Tektronix 155-0109-001 ICs.

Repairs*. These days is precisely the above praised knob that give most of the problems to the Tektronix restorer, but in most cases it is not too difficult to bring it back to the original operation. Besides the cam switches cleaning (see the dedicated pages in this book), there are two attention points:*

- *the the main and the delayed sweep switches must be synchronized, i.e., they must "click" exactly together. Rotating the two knobs together, the "click" must be sharp and clear;*
- *adjust properly the microswitch marked as 83 in FIG.1 EXPLODED mechanical assembly drawing in the manual 070-1342-00 (no. 92 in manual 070-1342-01).*

1


2

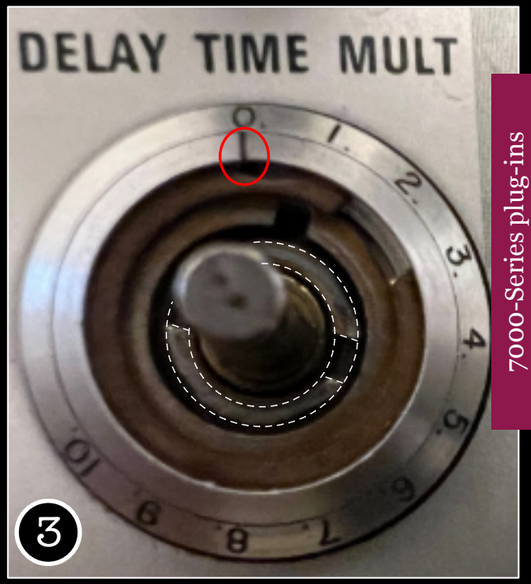
More detailed instructions. *The manual 070-1342-00 can help in that but the instructions related to the TDoDT switch adjustment are well hidden. They are at page 3.6, point 13 of the list ("Observe the following precautions...") (pg. 5.7 in manual 070-1342-01).*

Capacitors *A typical 7B53A (and 7000-Series in general) problem are also the Tantalum capacitors. Same of them are easy to diagnose, because they simply explode or short. Others, like C589 or C679, have a resistor in series and even shorted don't explode. They simply prevent the main sweep (C589) or the delayed sweep (C679) to operate.*

❶ On some 7B53A the sockets for the round ICs are not of the plastic type but are just pins sockets directly soldered on the PCB (like the transistors). The spare ICs that I could find, have however short pins and cannot been bent to match the PCB pinout. In this case, it's necessary to patiently resolder each pin adding a resistor rheophore to regain the missing length.

❷ The switch no. 83 described in the text senses when the two knobs are paired and must be properly adjusted. It is no. 92 in manual 070-1342-01).

❸ The DELAY TIME MULT knob is a precision gear and is indeed very robust and reliable. When it seems "loose" or imprecise, maybe that you need only to tighten the ring nut that stays behind the knob itself (shown dotted in the photo on the right). Remember first to set the position mark (in the red circle in the photo) exactly vertical. When you reassembly the knob, check the proper alignment with the numbering and with the potentiometer.



3

The delay line

When you are studying a circuit behavior, you would often know what happened not only "after" the trigger event (delayed sweep) but what led to the trigger event, and thus "before" it. With modern Digital Storage Oscilloscopes, that is easy: they accumulate samples of the signal in a circular buffer and, when the trigger occurs, it's sufficient to read the stored samples from that buffer (the 7D01 logic analyzer plug-in gave some possibilities like that).

In an analog scope, you simply cannot start the sweep before the trigger event, but in the 7000-Series we have available a palliative solution: the delay line, that allows to observe what happened few ns before trigger event. In the vertical signal path, before the delay line, there is a trigger pick-off which supplies an undelayed copy of the vertical signal to the trigger and sweep circuitry. Trigger and sweep circuitry need about 60 ns to react when presented with the trigger event. Without a delay line, the trigger event would already have come and gone before the scope can trigger and sweep. By sending the input signal through a delay line, the scope will have triggered and begun sweeping by the time the trigger event emerges from the delay line. Thus, the trigger event is drawn on the screen where the operator can see it, photograph it, or record it by other means.

In the photo: in the 7000-Series, a long, special twin-lead delay cable coil is used as a delay line (in this picture the 120ns delay line of 7904).

7B53A
construction

The structure of 7B53 is, a most 7000-Series plug-ins a little masterpiece. No room is wasted and also the disassembly is not too difficult.

Note, as for the mainframes, that every semiconductor device is mounted on socket, making easier the repairs.

Note also (in ❶) the ubiquitous Tektronix test signed label. Too bad that there is not a date, which could help determining the construction year, that can be only indicatively guessed by the year printed on the ICs (in the photo ❹, 1976).

❶ 7B53A left side view

❷ 7B53 right side view

❸ 7B53A top view

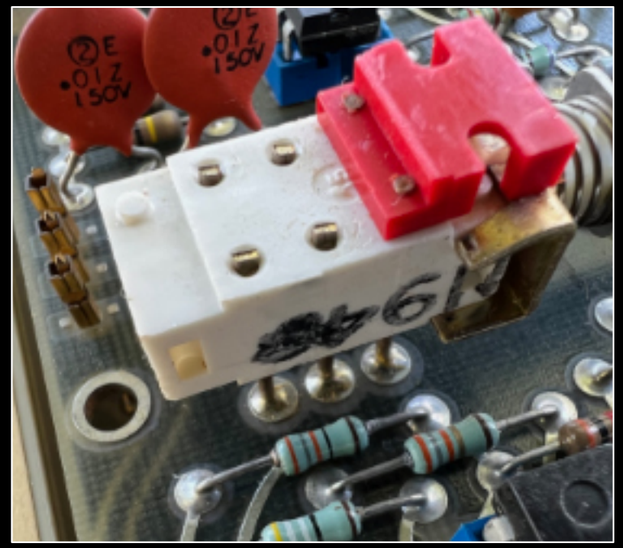
❹ The 7B53 depicted in photo ❷ is of the new type, with two Tektronix 155-0109-001 ICs, that substituted the former 6 ECL ICs (in the circle).

7B53A more details

A particular that shows the extreme attention also to details: a “pylon” to support and drive the passage of a shielded cable.

One of the beautiful capacitive trimmers, silver plated with ...true silver! Normally they become black, I polished this one for the photo.

The terrible Tantalum capacitors (the green little “drops”), one of the most frequent causes of failure in old Tektronix scopes.



Also the 7B53A uses the classic slide switches designed and built by Tektronix itself. They can also be the origin of troubles, but, in most cases, a simple cleaning with a specialized product can solve.

One of the things that I like so much in old instruments is the number of fascinating real knobs and buttons, that today are simply demanded to touch screens. The 7B53A has a lot of them but clearly ...not enough. So there was the possibility to change the behavior of the VARIABLE KNOB (the red one), which could operate on the main or delayed sweep frequency, or on the holdoff time, moving in a different position the P140 connector, as shown in this photo. As we will see, it is very useful to set it in DLY’D SWEEP position, using some digital plug-ins for precise measures.

Another option (P613, photo below on the right) allows the DLY’D GATE output signal to be connected to the DLY’D TRIG IN connector (set it as shown in the photo, the picture on the manual is misleading). You need also to press in the SOURCE INT/EXT button (INT position).

This is the only way to get to the DLY’D GATE output. The back connector on 76xx mainframes DLY’D GATE is really not connected (even if you set the switch on the back of the scope).

7B80 & 7B85 near digital

In 1976, the 200MHz 7B70/7B71 couple was not any longer sufficient to cover the requirements created by the introduction of the 7904 mainframe, so they were replaced by the 400MHz 7B80/7B85.

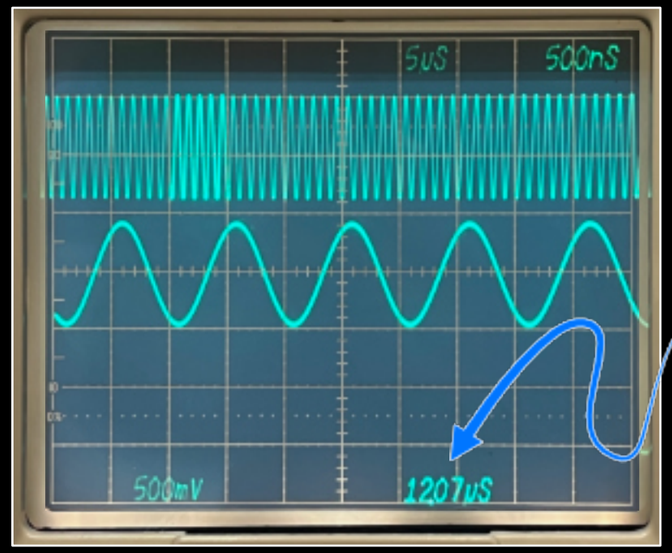
They received a completely new design, based on Tektronix custom ICs.

The 7B80 is a 400 MHz single time base plug-in without delay function for 7000-Series scopes, typically the 1971 7904 or the 7800-Series, e.g. 1974 7844.

The 7B85 is a 400 MHz delaying timebase with digital readout capability for delay and delta time. The delay function differentiates the 7B85 from the otherwise similar 7B80.

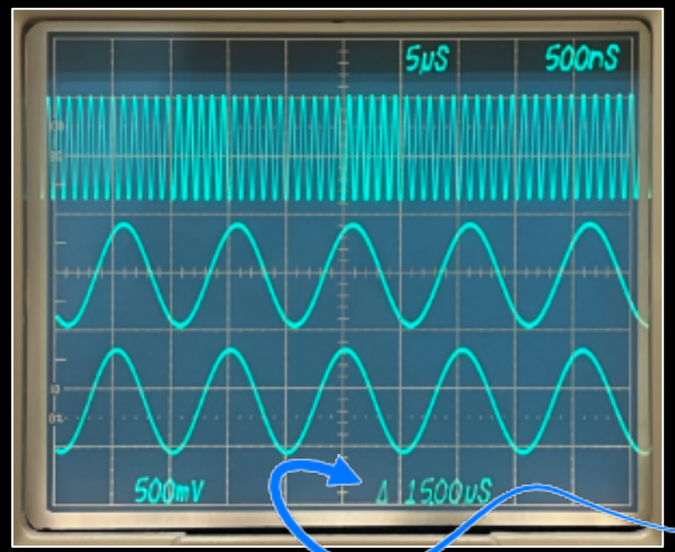
The new plug-in pair offered many possibility to be used in a four-bay mainframe, as we will try to describe with more details on the next pages. The more appealing feature of the 7B85 is the digital display of the delay time, a nice novelty at the time.

1976



In this picture, we see the 7B85 in A bay, operating in the classic delaying timebase role, triggering the delayed 7B80 timebase, that produces the zoomed B trace.

But the absolute novelty was the exact delay time, showed in the readout system. Today is nothing, but then it was a real innovation, that avoided the operator the possibility to do mistakes. It is not a real digital delay, but just the voltage measurement of a ramp signal; however the effect definitely digital!

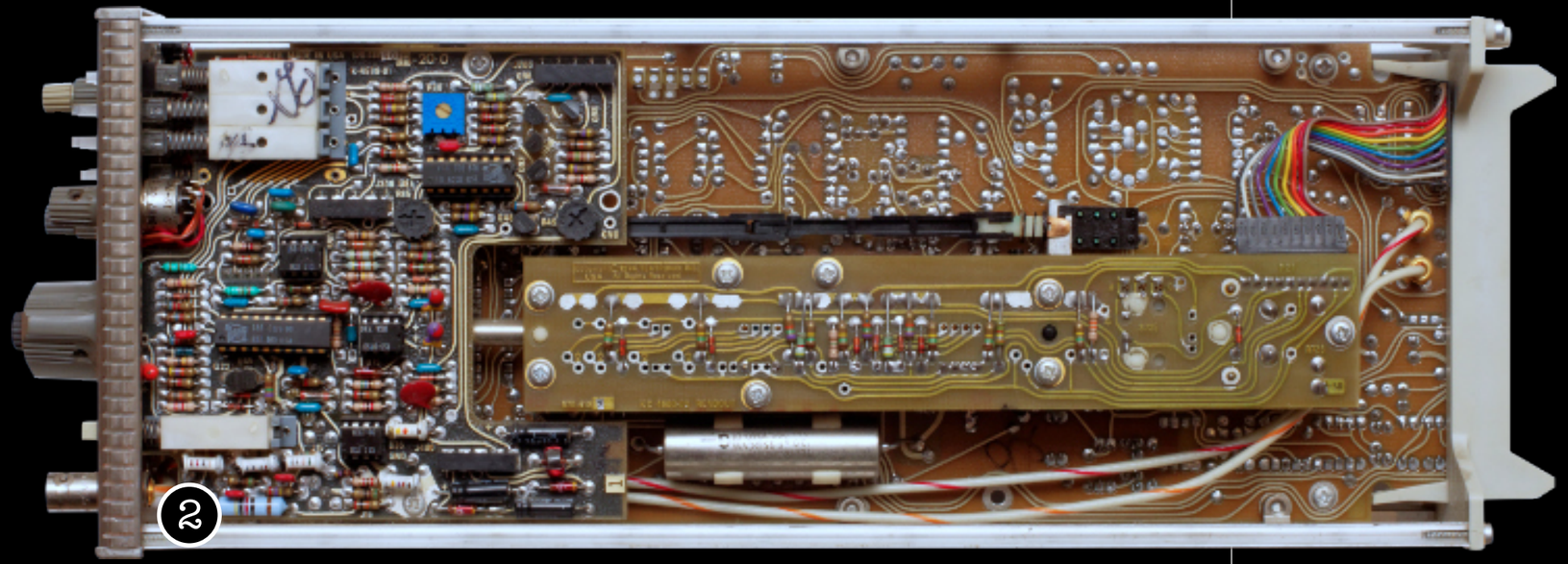


Here we go even further, anticipating the theme of the cursors, that we will afford talking about the 7D15 timer/counter. With the 7B85, you can add a second enhanced zone on the trace, long as the first, but movable back and forth as you like. This area can be displayed separately in a third trace on the CRT. The time difference between the start of the first area and the second is automatically displayed with a "Δ" sign in front.

The 7904, with two independent horizontal bays, offers multiple capabilities to display your signals, not last to display two independent traces at the same time, each with a different timing.

1976

1



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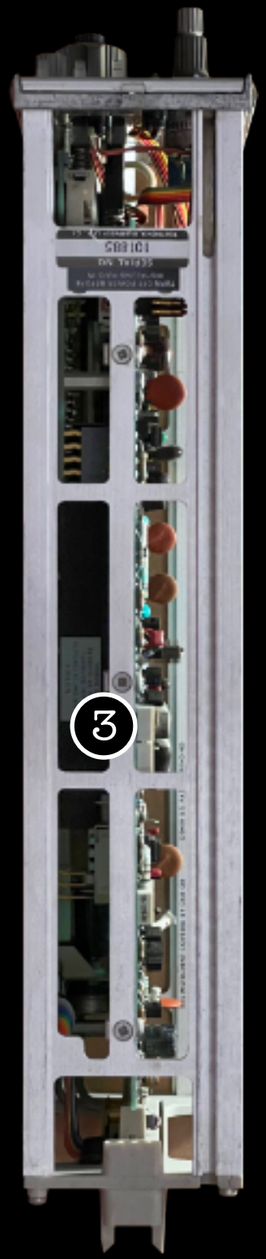


3

7B80
time base

The 7B80 uses the 155-0126-00 trigger amplifier followed by the 155-0109-01 trigger detector. Differently from 7B70/71, does not uses relays anymore.

Option 2 adds support for X-Y mode via an added "Display mode" switch. When X-Y mode is selected, the X-axis signal is taken from the internal trigger path.

The 7B80 uses the ±50 V supplies from the mainframe.

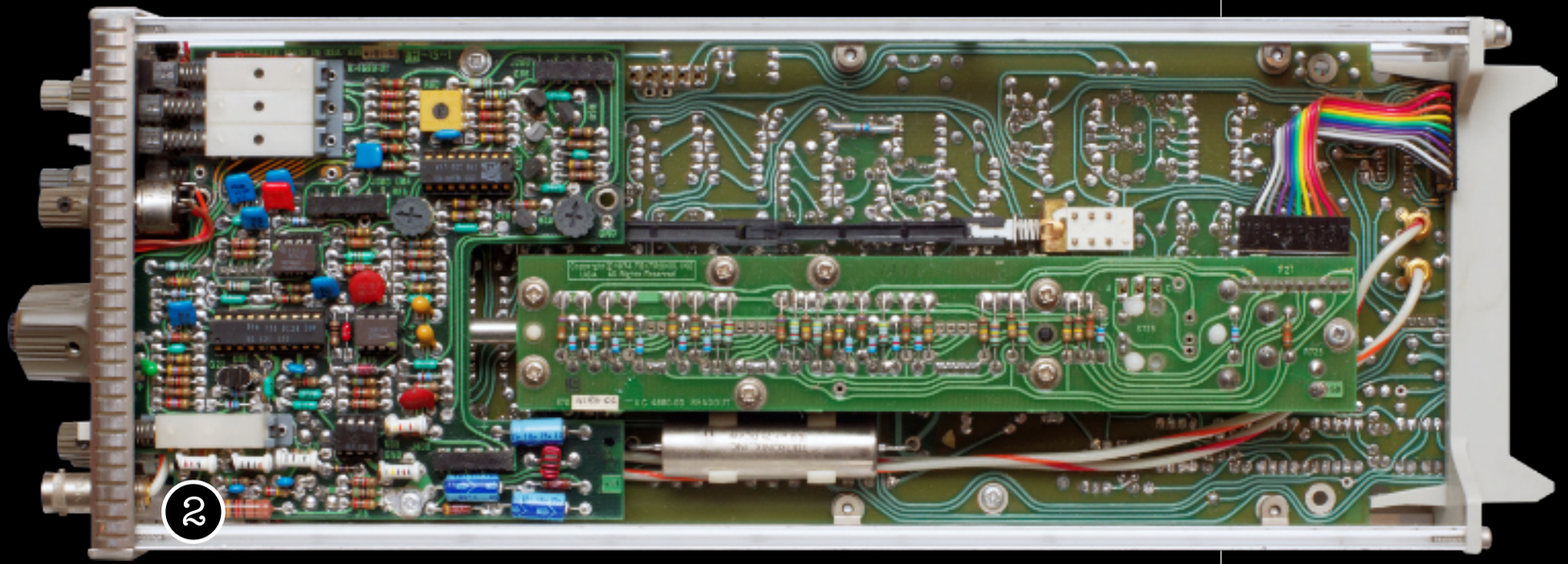
Other specifications:

- *Sweep: 10 ns/div to 5 s/div (1–2–5), ×10 magnifier (down to 1 ns/div), variable sweep (up to ×2.5) and holdoff (up to ×2 sweep lengths at 20 ms/div and faster)*
- *Excluded sweep: first 10 ns in 78xx, 79xx; first 20 ns in 77xx; first 50 ns in other mainframes*
- *Sweep/trigger modes: peak-peak auto, auto, norm, single sweep*

❶ 7B80 left side view
❷ 7B80 right side view
❸ 7B80 top view

1976

1



2

3

7B85 delaying time base

The 7B85 uses a 155-0185-00 digital voltmeter IC (U686). A ramp generator is started when the trigger signal arrives. The delayed sweep is started when a comparator detects that the ramp has reached a control voltage, set by the front panel knobs on the 7B85. The control voltage is proportional to the amount of delay.

The digital voltmeter in the 7B85 digitizes the control voltage and displays it on the oscilloscope readout, thereby providing the operator with a precise readout of the delay.

For the remaining, 7B85 is very similar to 7B80.

❶ 7B80 left side view
❷ 7B80 right side view
❸ 7B80 top view

1976

Digital plug-ins

Digital plug-in open a whole new world of application for the 7000-Series mainframes

Digital plug-ins

Differently from others, the 7000-Series, thanks to its long-sighted architecture, was capable to adapt to the changing world, and so survive for an incredible long time.

Very soon Tektronix understood the potential of the digital technology, and already in 1972, the 7D15 and other digital plug-ins were introduced, adding to the 7000-scopes the capability of precise frequency and time measurement.

But the real turning point came in 1976, when the wonderful 7D01 was introduced, opening a full new world of applications, and, at the same time, enabling the previous users to upgrade their existing equipment.

Still a long way from the 7854 and modern Digital Storage Oscilloscopes, but the process has been started.

1972

1976

1977

1976

Note: the 7A13 is not a digital plug-in but an amplifier. I included here the 1976 model for its built-in digital voltmeter.

7D15 225 MHz universal timer counter

The 7D15 makes its first appearance in the 1973 Tektronix catalog on pages 69-70

An announced success

According the Tektronix "Marketing Sales Release", August 11, 1972, the customer requests for a product like 7D15 outweighed the sum of all the others by a factor of three. With an unusual degree of confidence, Tektronix forecasted that the 7D15 Universal Counter/Timer would substantially outsell both of the existing digital plug-ins 7D14 and 7D11.

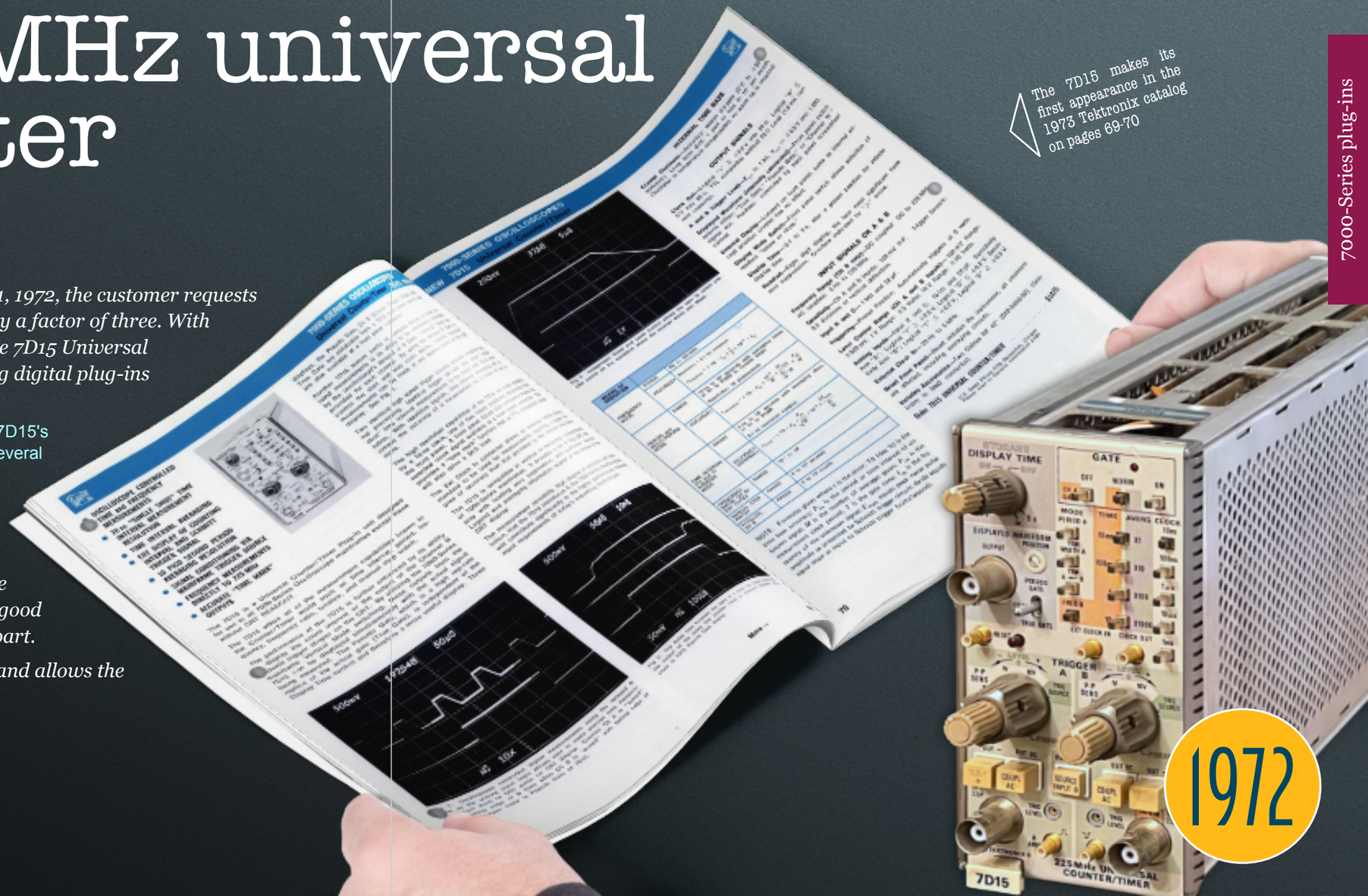
The features and benefits described below are very real ones. The 7D15's performance as a universal counter is among the best existing. In several respects it is best. The addition of our "see what you're counting" capability is even more valuable here than in the 7D14.

Basic functions

I admit that understanding the 7D15 was not easy for me. The documentation is rather detailed, but, in my opinion, lacks a good general overview, that we will try to supply here, at least in part.

*Basically, the 7D15 is a **general purpose counter/timer**, and allows the following most important functions:*

- *frequency measurement;*
- *period measurement;*
- *event counting.*



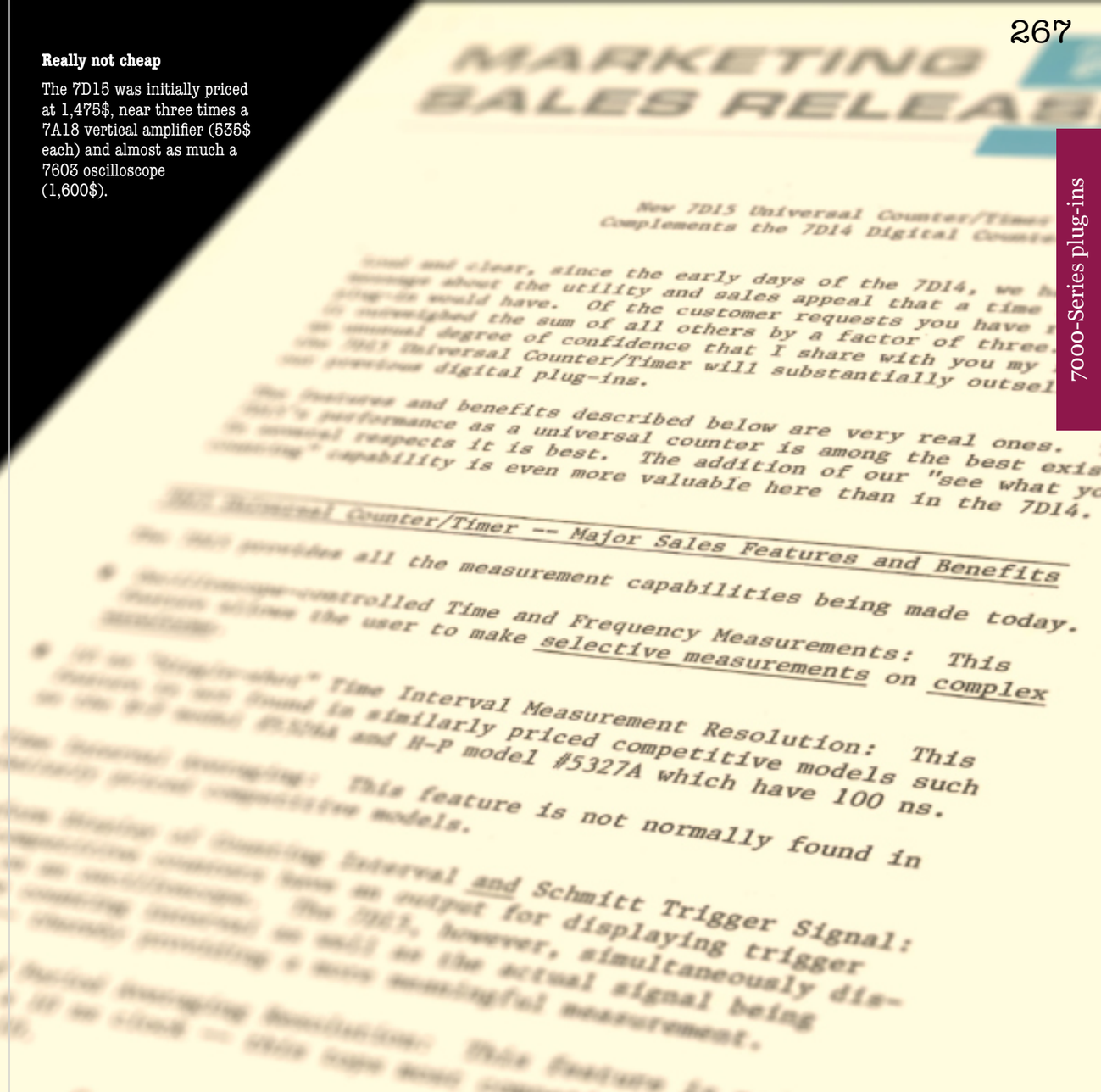
Complex measurements

The 7D15 is, however, a complex equipment and allows many kind of measurements. The triumphalist sales release document stated that it provided all the measurement capabilities that users could require:

- **Oscilloscope-controlled time and frequency measurements**: this feature allows the user to make selective measurements on complex waveforms;
- **10 ns "single-shot" time interval measurement resolution**: This feature was not found in similarly priced competitive models such as the H-P model #5326A and H-P model #5327A which have 100 ns;
- **Time interval averaging**: this feature is not normally found in similarly priced competitive models;
- **Waveform display of counting interval and Schmitt trigger signal**: some competitive counters have an output for displaying trigger levels on an oscilloscope. The 7D15, however, simultaneously displays the counting interval as well as the actual signal being measured -- thereby providing a more meaningful measurement;
- **10 picosecond period averaging resolution**: this feature is made possible with a 10 ns clock -- this tops most competitive models by a factor of 10;
- **Signal conditioning via mainframe trigger source**: exclusive with 7000-Series, the different type of vertical plug-in units can provide signal conditioning. Plug-in is routed to the horizontal compartment, the vertical plug-in can be used for signal conditioning such as with a differential amplifier, a high gain amplifier, a current probe amplifier, etc.
- **Frequency measurements directly to 225 MHz**: this is a much higher frequency than competitive models such as H-P model #S326A and H-P model #S327A (which count directly to 50 MHz) and Systron Donner model #6150 series (which counts directly to 200 MHz);
- **Accurate "time mark" outputs:** useful for calibrating oscilloscopes, etc. (10 ns, 100 ns, 1 µs, 10 µs, and 1

Really not cheap

The 7D15 was initially priced at 1,475$, near three times a 7A18 vertical amplifier (535$ each) and almost as much a 7603 oscilloscope (1,600$).



MARKETING
SALES RELEA

New 7D15 Universal Counter/Time
Complements the 7D14 Digital Counte

...and clear, since the early days of the 7D14, we h...
...message about the utility and sales appeal that a time ...
...plug-in would have. Of the customer requests you have ...
...outweighed the sum of all others by a factor of three. ...
...an unusual degree of confidence that I share with you my ...
...the 7D15 Universal Counter/Timer will substantially outsel...
...our previous digital plug-ins.

The features and benefits described below are very real ones. ...
...DVM's performance as a universal counter is among the best exis...
...in several respects it is best. The addition of our "see what yo...
..."viewing" capability is even more valuable here than in the 7D14.

7D15 Universal Counter/Timer -- Major Sales Features and Benefits

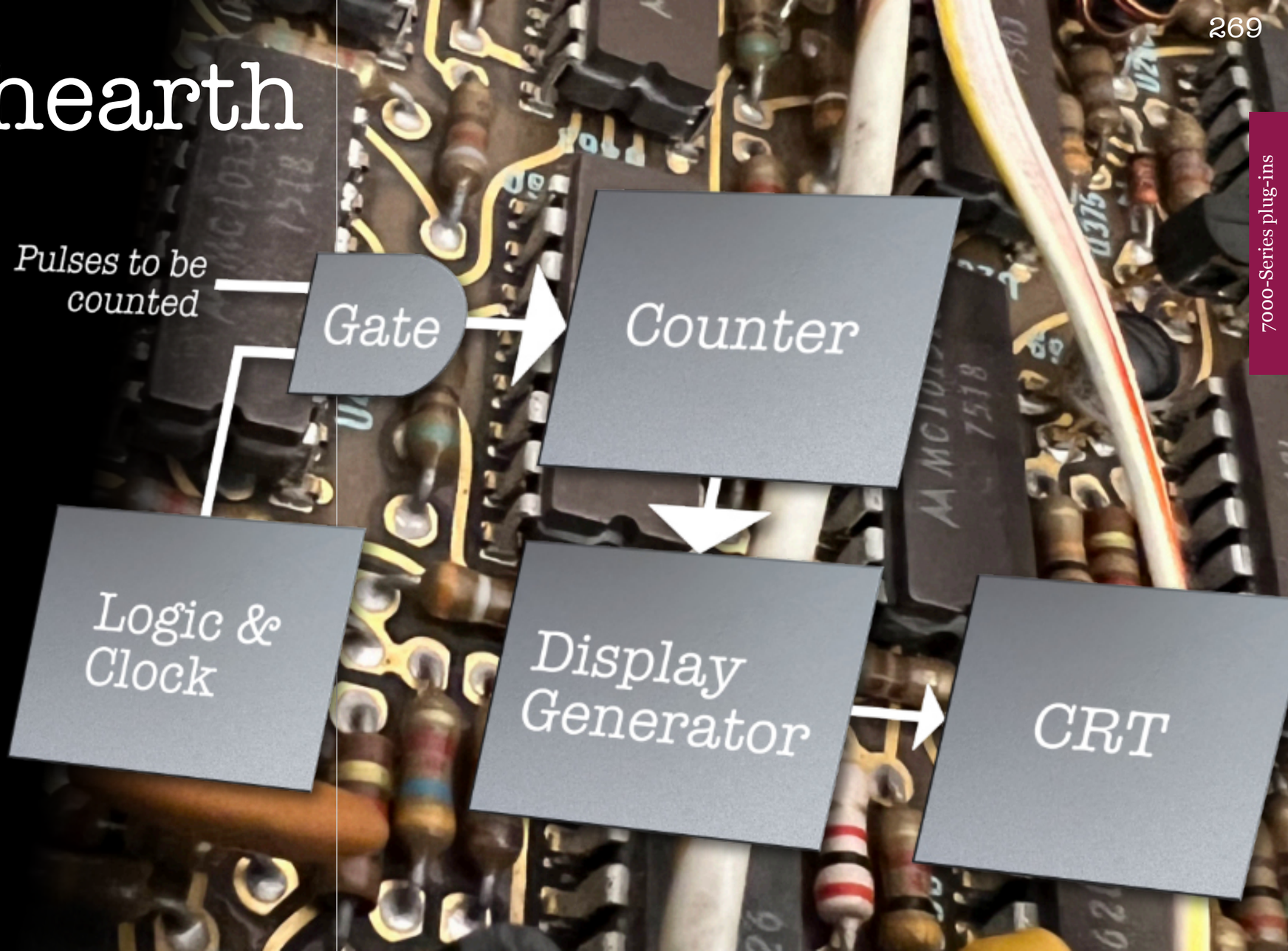
The 7D15 provides all the measurement capabilities being made today.

- Oscilloscope-controlled Time and Frequency Measurements: This feature allows the user to make selective measurements on complex waveforms.
- 10 ns "single-shot" Time Interval Measurement Resolution: This feature is not found in similarly priced competitive models such as the H-P model #5326A and H-P model #5327A which have 100 ns.
- Time Interval Averaging: This feature is not normally found in competitive models.
- Waveform Display of Counting Interval and Schmitt Trigger Signal: Some competitive counters have an output for displaying trigger levels on an oscilloscope. The 7D15, however, simultaneously displays the counting interval as well as the actual signal being measured -- thereby providing a more meaningful measurement.
- 10 Picosecond Period Averaging Resolution: This feature is made possible with a 10 ns clock -- this tops most competitive models by a factor of 10.
- If no cheap -- this tops most

A gate as a hearth

*The heart of 7D15 is a **gate**, that, when open, allows pulses to reach a **counter**. When the gate closes, the value of the counter is transferred to the CRT **display**, using the readout system of the 7000-series. Then the counter is reset and a new cycle begins.*

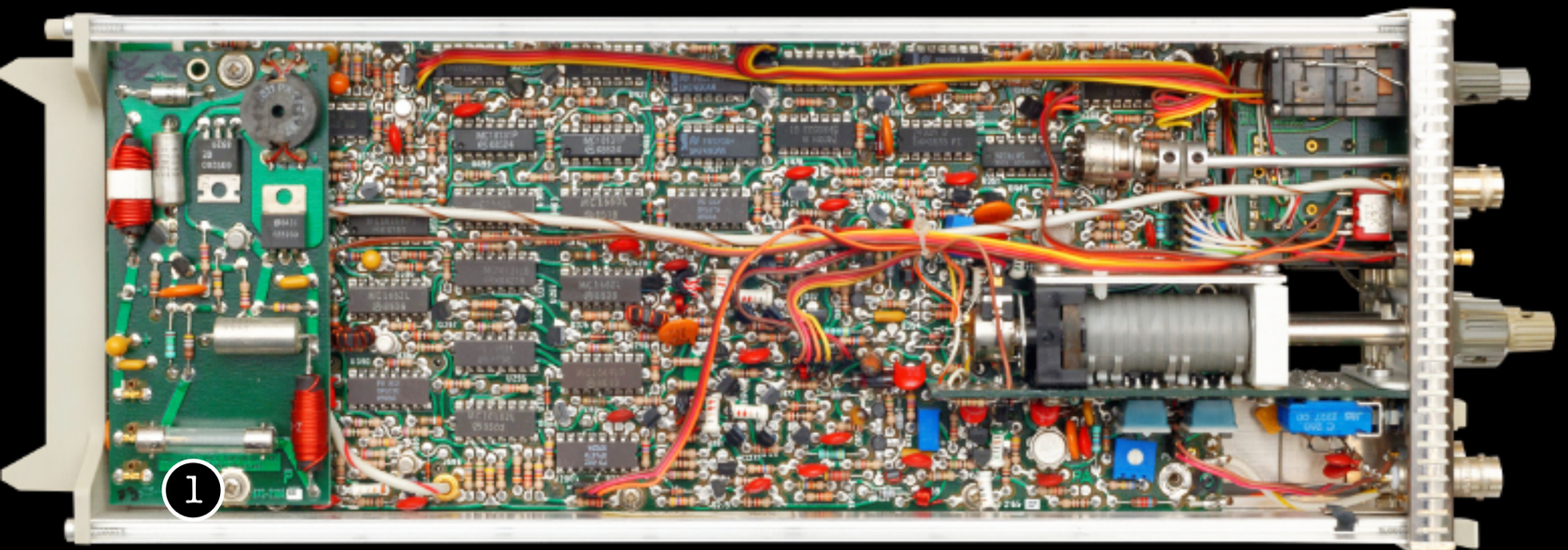
*For the **frequency measurement**, the gate is kept open for a precise time and the pulses from the unknown signal are counted. For the **period measurement**, the gate is open and closed by the unknown signal and the pulses from a precise clock are send to the counter.*



What does it mean "gate"?

Before affording this point, we need a clarification: the term "gate" is misleading, because Tektronix uses it with at least three different meanings:

- *when you have a trace on the screen, a corresponding signal **GATE OUT** is produced, that stays high for the time of the whole trace (main sweep); it can be accessed by the BNC connector on the back of the scope;*
- *when you have a trace portion highlighted, a corresponding signal **DLY'D GATE OUT** is produced (not from the back BNC connector, you need to get it out the 7B53, see below), that stays high for the time of the highlighted segment of the trace on the screen, while the +GATE OUT stays high for the delay time (main sweep);*
- *the third meaning is the **7D15 gate**, as above described.*



7D15 construction

Looking at these beautiful TekWiki photos, I thought that, in 7D15, Tektronix had renounced to IC sockets. When I received my 7D15, I discovered that it is not so: even invisible, all the ICs have their own socket. That makes much easier today restoration.

To be noted also the cam and button switches, as most Tek plug-ins, and the big 5MHz integrated oscillator.

Note also the internal/external clock slide switch: again, Tektronix could not fit all the required controls on the front panel and something ended up staying out. This is a sign of the willing to offer always the maximum of flexibility to the users.

The 7D15 was an important products. Tektronix said that "...the performance of the 7D15 could never have been achieved in such a compact package without the use of five Tektronix-manufactured integrated circuits. At least 100 people played some role in bringing the 7D15 into production.

❶ 7D15 right left view; ❷ 7D15 right side view; ❸ 7D15 top view

ECL logic

In the past, I used to work on circuits that used TTL levels almost everywhere. The 7D15 uses instead a mix of TTL ICs, discrete components and ECL ICs, and this was for me the first opportunity to get acquainted with the ECL family.

ECL (emitter-coupled logic) is a high-speed logic family, built with integrated bipolar transistor.

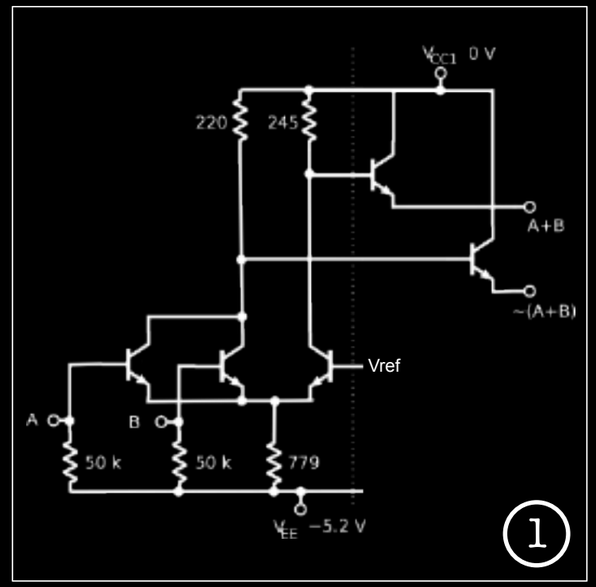
Differently from TTL, in ECL, the transistors are never in saturation and the signals have a small voltage swing (0.8 V), with high input and low output impedance. The transistors change states quickly, gate delays are low, and the fanout capability is high.

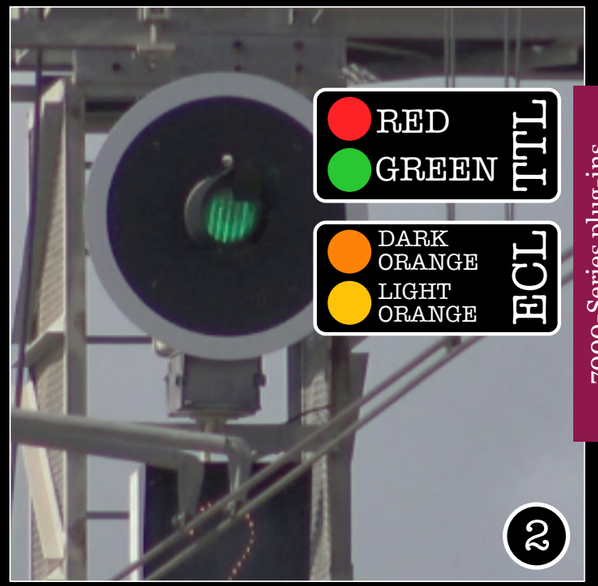
This is obtained using a differential amplifier. One of the inputs is connected to a fixed voltage reference, the other one is the gate input. The input can be above or below the reference voltage, avoiding the saturated (fully on) region of operation and its slow turn-off behavior. So the current is almost constant: the amplifier simply "steers" the current between the two legs of an emitter-coupled pair.

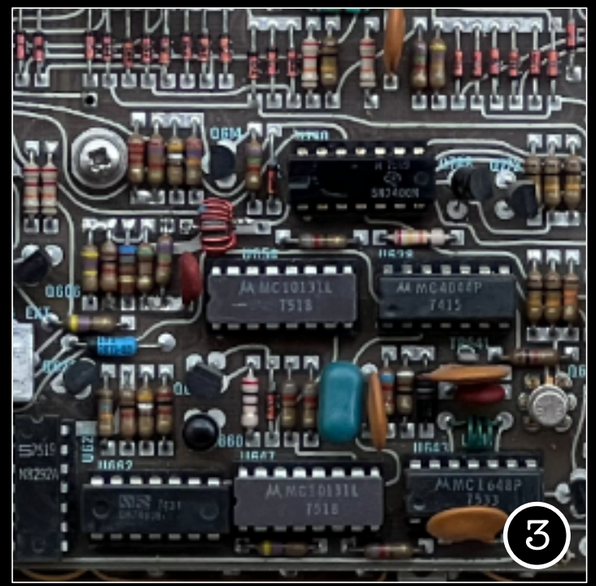
This almost constant (high) current draw minimizes delays and glitches due to supply-line inductance and capacitance, and the complementary outputs decrease the propagation time of the whole circuit by reducing inverter count.

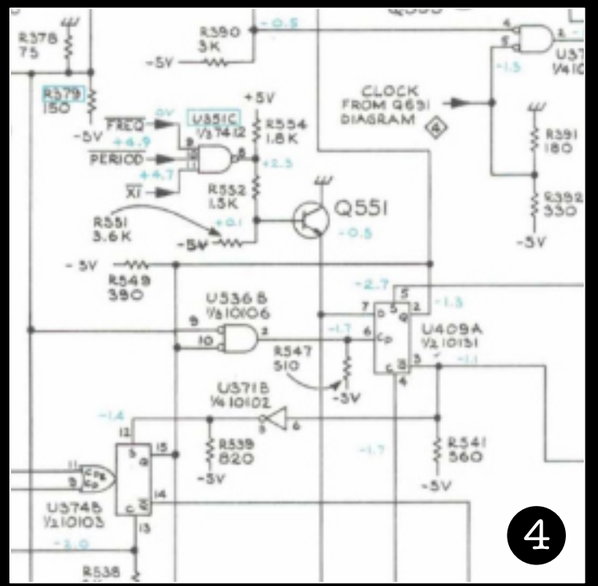
Today is different (PECL), but, at that time, ECL logic required -5V power supply. The 7000-Series mainframes had not a -5V voltage, so 7D15 has a dedicated switching power supply, fed by -15V.

❶ A real ECL gate schematic diagram; ❷ ECL logic is similar to a railway traffic light, where, instead of green and red light, you have a light orange and a dark orange light. A differential amplifier resolves this small difference; ❸ on the 7D15 board you can find TTL gates, ECL gates and discrete transistors; ❹ most often the discrete transistors are used as level translator (but not only).









My beloved 7D15

I could find my 7D15 by Radiosurplus Elettronica, one of the best Italian company specialized in surplus and measurement equipment. I found it on their web site, where it was declared as "not tested". My major concern was that it could have some special Tektronix ICs broken. They are very expensive and some of them are very hard to find. I wished however to get hold of this unit, so I decided to afford the risk.

Waiting the 7D15 to arrive, I took advantage for studying its documentation, finding it a little scaring; the circuit is intricate enough...

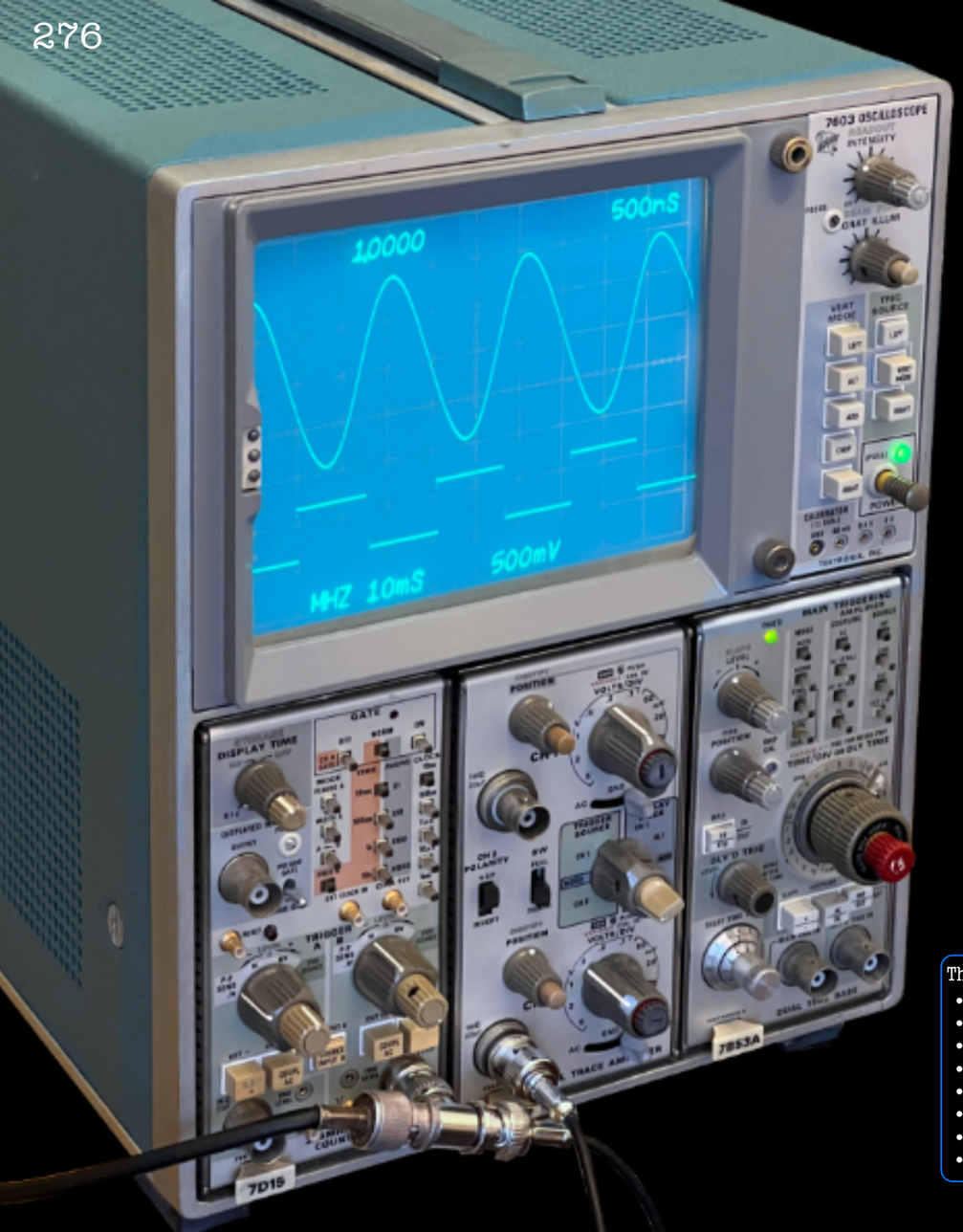
I planned a very thorough examination of the stuff before powering it on, but when it arrived I could not resist and immediately tried to plug it into a 7603. First: no smoke; second: no mainframe claims, the power remained on. After few seconds, the display came on: the readout system, that mainly worried me, was happily running. A first sigh of relief!

After few minutes, the mainframe power goes off. That didn't frighten me too much: it could be a typical Tantalum capacitor fail, and it was (C931 on +15V). Once I replaced it, I started trying to understand what was working and what not. I spent (lost, according my wife) one day and a half to find the other two problems, navigating in the knotty schematics. They are complex indeed, but I find myself much more comfortable with this kind of circuits respect to amplifiers and analog circuits in general. Eventually the problems were:

- *the GATE OFF button had an imperfect contact, that sometime blocked the gate operation (just move the connectors and clean);*
- *a 74L00 (U264) was faulty. It prevented the reset circuit at the end of a measure, so the counter went on with an endless count. I had not a 74L00 spare; a pull-down temporary solved the problem. Later, I replaced the 74L00 with a 74HC00, and it worked smoothly.*

To conclude: I have now a perfectly working 7D15, am very happy with my purchase and grate to the seller. As you can in the photo, I still need only to restore the button keys, using the technique that I describe in this book itself. Update: I did it and the result is in the photo on the right.

In background in the photo: a WW2 WS 19 MkII receiver transmitter, a Siemens e311 receiver and a BC-221 frequency meter.



Example of frequency measurement with 7D15.

The trace above is the input signal, the trace below is the output of the trigger signal conditioner.The measured value is displayed top left ("1.0000"), while the units ("MHz") are right below.

The setup for this test is:

- GATE: NORMAL
- MODE: FREQUENCY
- TIME: 10mS
- STORAGE: ON
- DISPL'D WAVEF: CH B
- DISPLAY TIME: 0.1 s
- B TRIG SOURCE: INPUT B
- SENSIT/LVL: as required

Measuring frequency

*Let's return now to the question "how to **open** and **close** the **7D15 gate**"? The 7D15 offers you various ways to do that, so that to offer the best versatility.*

*Let's analyze the case of **frequency measurement**. In this mode, the 7D15 uses use a precise clock signal (from 10ms to 10s) to open and close the gate, while the counter counts the pulses coming from the unknown signal.*

Real signals from the real world

*The input signal from the real world cannot be, in general, directly sent to the counter, but must be **conditioned**, i.e., transformed in a precise value rectangular pulse.*

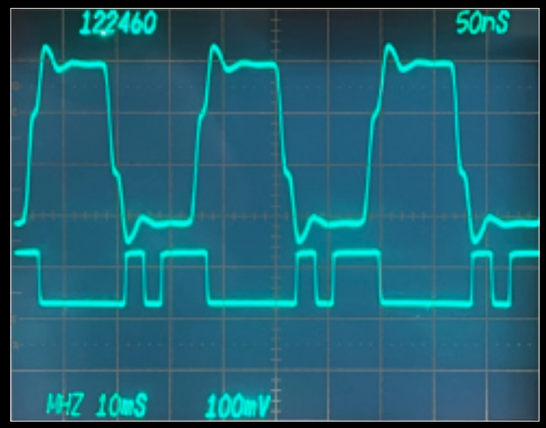
*For this purpose, the 7D15 has two **inputs**, **A** (left) and **B** (right); each of them has a trigger circuit with the typical trigger controls (level, AC/DC, polarity). As normal, each trigger includes a pulse shaper to have only an high or or low level in output.*

*For the frequency measurement, we must use the **B input**. But, if the input signal is not so clean, who can ensure that the trigger is operating correctly? A strong ringing could, for example, lead to multiple pulses and so to a wrong frequency value (see the photo below).*

The 7D15 has a very practical way to "see" the input signal and superimpose to it the conditioned signal produced by the trigger. It is sufficient to:

- *send the input signal both to a vertical channel of the scope and to the B input;*
- *set the switch DISPLAYED WAVEFORM to CH B, to show the conditioned signal.*

The photo on the right shows this condition. As you can see, the conditioned signal is not representative of the input signal, and the read frequency is 12.246 MHz. In this case, we need only to adjust as necessary the input B trigger level knob to see the real frequency (6.123 MHz).



Screen cursors

With modern DSOs, we are used to have two pair of cursors, one for time and one for amplitude. It is interesting that this basic concept arrived relatively late. With 7D15 you can add to 7000-oscilloscopes a sort of cursors for time, but it was not so explicitly stated in the original documentation.

To have these cursors you need also a 7B53A time base, but you need to apply a little modification to it, if not already done, setting the P140 and P613 internal connectors, as described in page "7B53 more details" in this document.

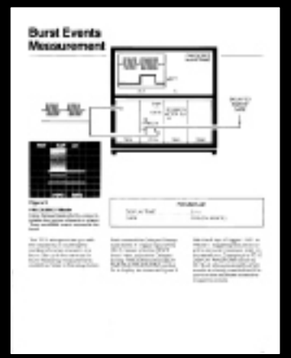
Doing so, you get the cursors using the delayed time base to highlight a portion of a displayed trace. You can continuously move the beginning (left cursor) and the end (right cursor) of the highlighted portion as follows:

- *you can move the left cursor with the DELAY TIME MULT knob;*
- *you can move the right cursor with CAL red knob.*

Now you have available the DLY'D GATE OUT signal that you can route to the A input of the 7D15. This signal is not available on the back panel of the scopes (honestly I did not understand why) as it should be, but from the 7B53A DLY'D TRIG IN BNC connector (press the INT/EXT button).

Burst events counting

Let's examine an example where we want to count the pulses in a burst inside a complex signal. The DLY'D GATE OUT signal from the 7B53A is routed to the 7D15 A input. Adjust the Delayed Sweep TIME/DIV and the DELAY TIME MULT control for a display as shown in drawing. With the B input trigger LEVEL knob set to the PRESET position, triggering should occur at the zero volt crossover point on the waveform. Changing the 7D15 DISPLAY WAVEFORM switch to CH B will show you exactly which events are being counted and the point on the waveform where the triggering occurs.



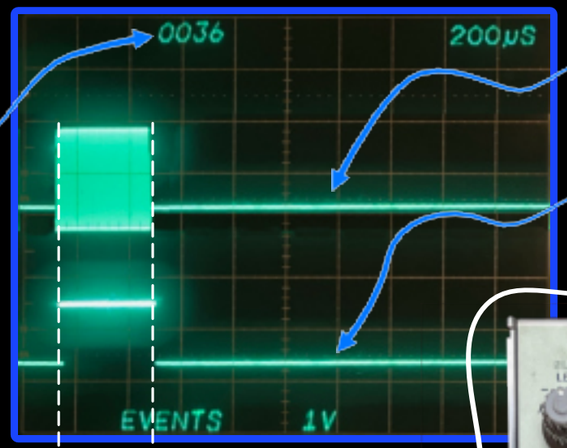
The pulses count

The incoming signal

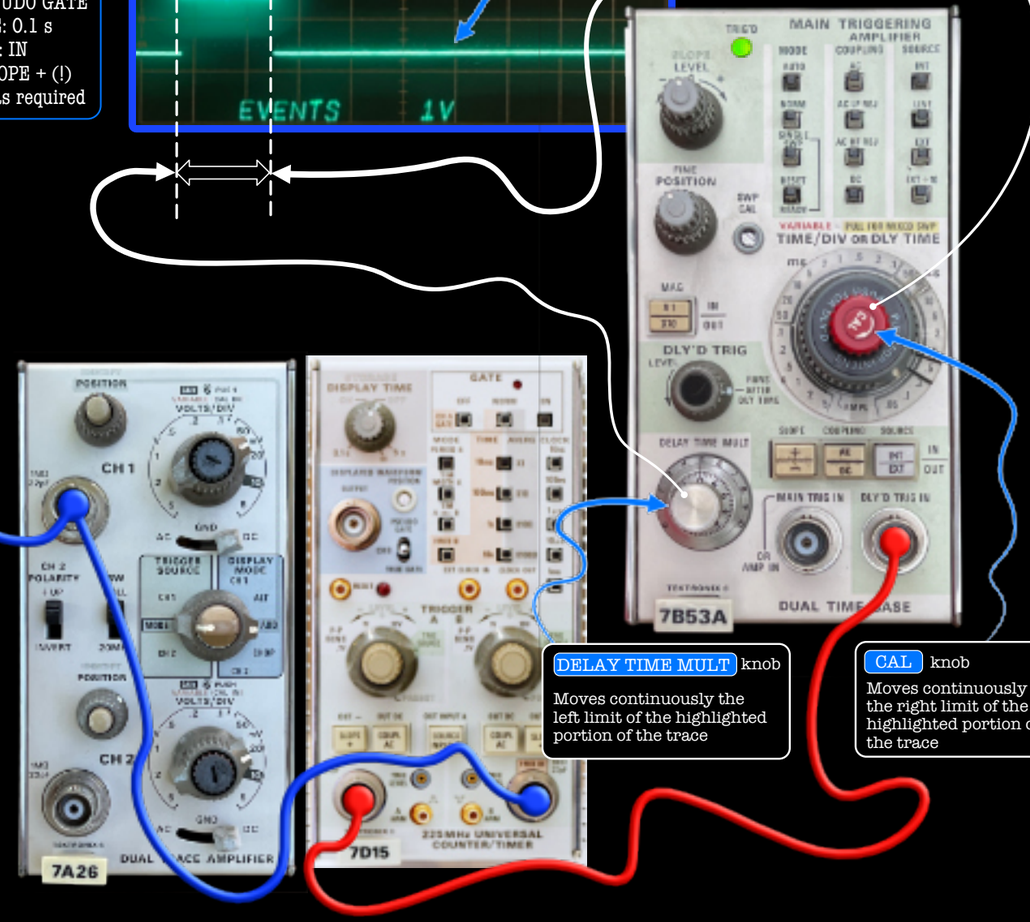
The PSEUDO GATE

The setup for this test is:

- GATE: CH A GATE
- MODE: FREQ
- TIME: 10mS
- STORAGE: ON
- DISPL. W.: PSEUDO GATE
- DISPLAY TIME: 0.1 s
- SOURCE INP B: IN
- CH A TRIG: SLOPE + (!)
- SENSIT/LVL: as required



The incoming signal



DELAY TIME MULT knob

Moves continuously the left limit of the highlighted portion of the trace

CAL knob

Moves continuously the right limit of the highlighted portion of the trace

Measuring period

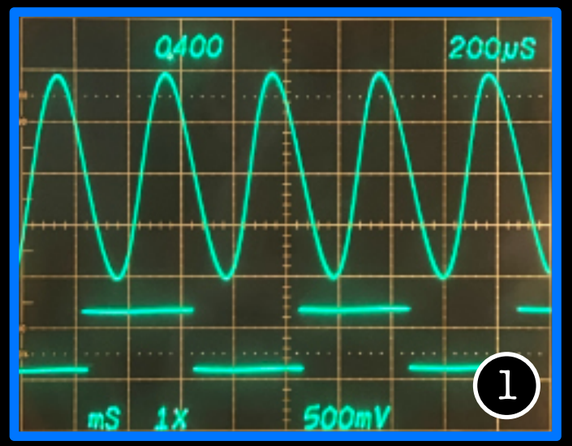
As we well know, period is just the reciprocal of the frequency, but period measurement is normally used for low frequency signals, typically below 50-100Hz, because it is more practical to deal with 475 ms instead of 2.185263 Hz.

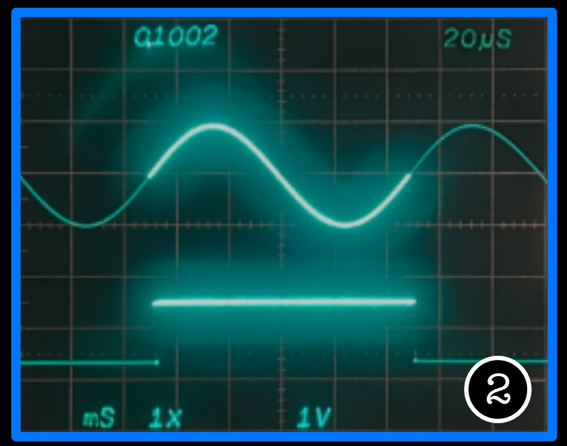
To measure period, the 7D15 gate is opened and closed by the input signal lead to input A. The number of clock pulses counted by the counter represents the period value. In this case, we need to be sure that the gate signal period corresponds exactly to the incoming signal period. To do that we must:

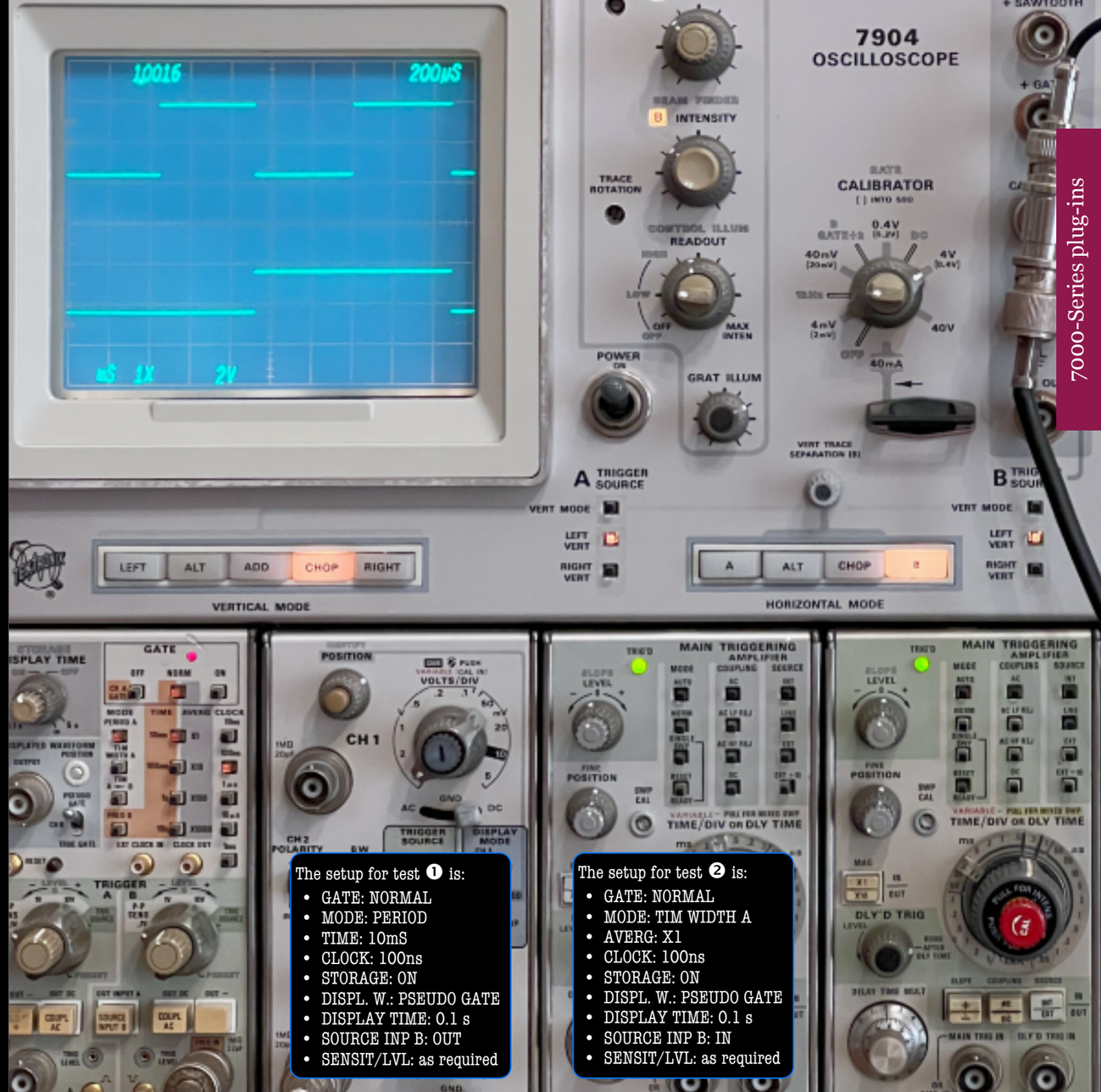
- *send the input signal both to a vertical channel of the scope and to the A input;*
- *set the switch DISPLAYED WAVEFORM to TRUE GATE or PSEUDO GATE. The latter position increases the refresh frequency of the display and makes it more readable.*

In the photo ❶ below we can see a 2.5 kHz signal, with a read value of 0.400 ms.

A possible different approach to the period measurement is the one of the manually adjusted cursors, in a manner similar to that described on the previous two pages, as shown here in photo ❷. Less automatic but practical. On the right: the 7D15 inside the 7904, checking the calibrator signal.







More examples

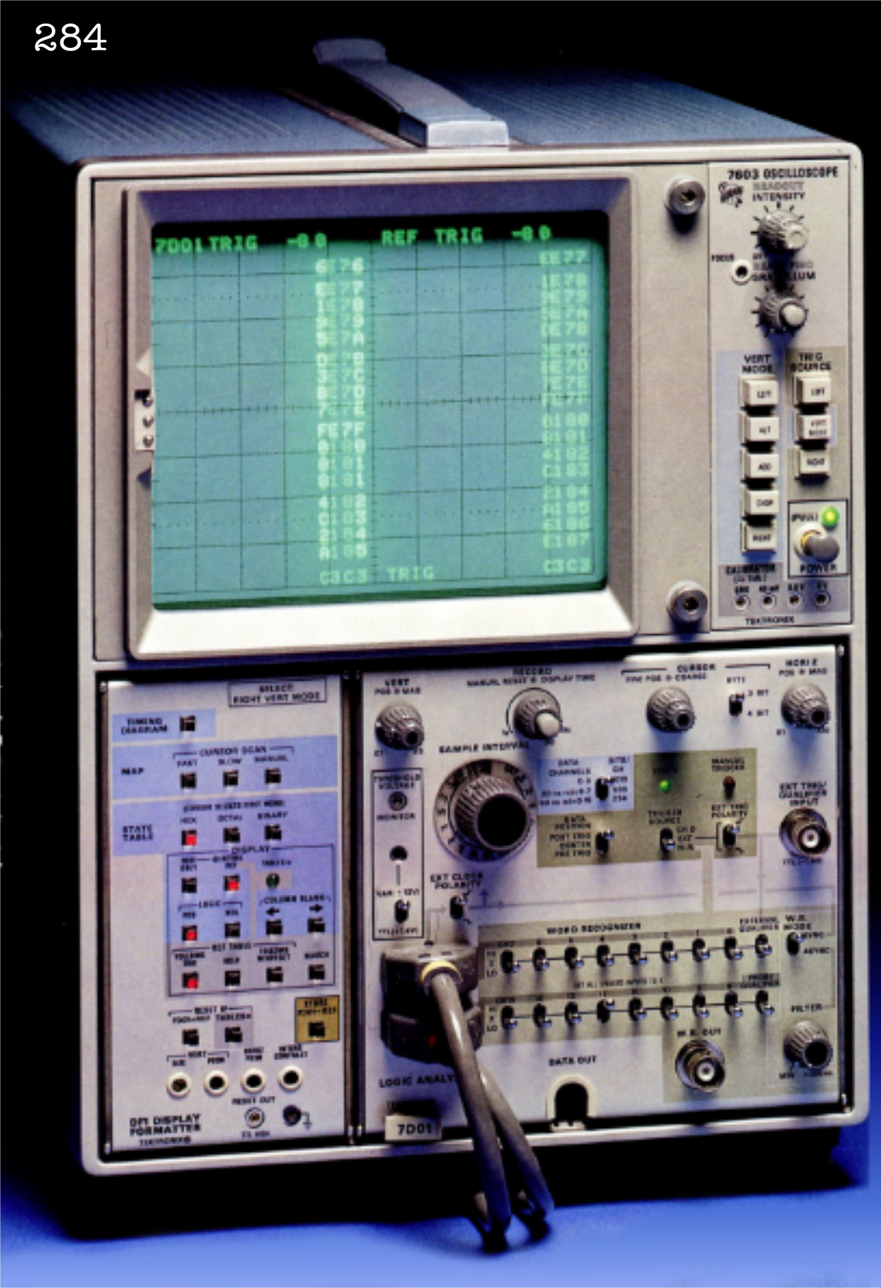
A great part of the information contained in this book was taken from the Tektronix 42W-5017 application guide, "Increased measurement accuracy using a 7D15 universal counter/timer". Its purpose is to introduce to the 7D15 Universal Counter/Timer and its many measurement capabilities, and to show how to make a variety of counting and timing measurements with greater versatility, speed, accuracy, and resolution. Many possible measurements are described, such as:

- *Repetitive Signal Frequency Measurement*
- *Burst Frequency Measurement*
- *Burst Events Measurement*
- *Waveform Period Measurement*
- *Selective Period Measurements*
- *Waveform Width Measurements*
- *Time Interval Measurements*
- *Selective Time Interval Measurements*
- *Time Interval Measurements on Two Separate Signals or Two Signals with Different DC Levels*
- *Phase Measurements*
- *Ratio Measurement of Two Signals*

Each application is described in detail, with step-by-step instructions for set-up, interconnections, and control settings, so that to prove that the 7D15 Universal Counter/Timer is indeed a versatile, accurate, and easy to use measurement tool.

The document, downloadable from TekWiki, is interesting.

TEK
INCREASED MEASUREMENT ACCURACY USING A 7D15 UNIVERSAL COUNTER/TIMER IN ANY 7000 SERIES OSCILLOSCOPE
DELAYED SWEEP GATE
9



7D01 key specifications

Channels

- 4 channels at 1016 bits/channel, maximum external clock period 10 ns (100 MHz)
- 8 channels at 508 bits/channel, maximum external clock period 20 ns (50 MHz)
- 16 channels at 254 bits/channel, maximum external clock period 40 ns (25 MHz)

Sampling Rate

- 10 ns to 5 ms per sample (1–2–5) or external clock up to 50 MHz

Trigger Sources

- external
- channel 0 data
- 16 channel word recognizer
- manual

1976

7D01 logic analyzer

The 7D01 is a 16-channel logic analyzer plug-in for the 7000-Series scopes, which entirely change and extend the purpose of this product line. It was introduced in 1976 and can display a timing diagram, that can be positioned and zoomed using analog controls, thru the mainframe's readout system, to indicate the cursor position (on top) and the binary data pattern at the cursor location, using the two bottom readout fields. Its complexity is far from that originally conceived for a plug-in, and required thus the volume of even two drawers.

One year later the 7D01 introduction, its mating companion DF1 display formatter plug-in became available, offering a data domain display, i.e. a view of the same data that the 7D01 was able to collect, in form of digits, thru state and map tables. Those functions ought to be included in a good logic analyzer: ultimately, it was the balance of a technological debt, even at the price of three-plug-in total volume.

As you can see by the fonts, the DF1 had its own readout system, more modern and effective than that included in the 7000-Series mainframes. It was able also to generate the readout in timing diagram mode, allowing a 7D01 with DF1 (a set called 7D01F) to be used in mainframes without readout, e.g. the large-screen 7603N.

To compose full logic analyzer, you had to pay in total in 1977:

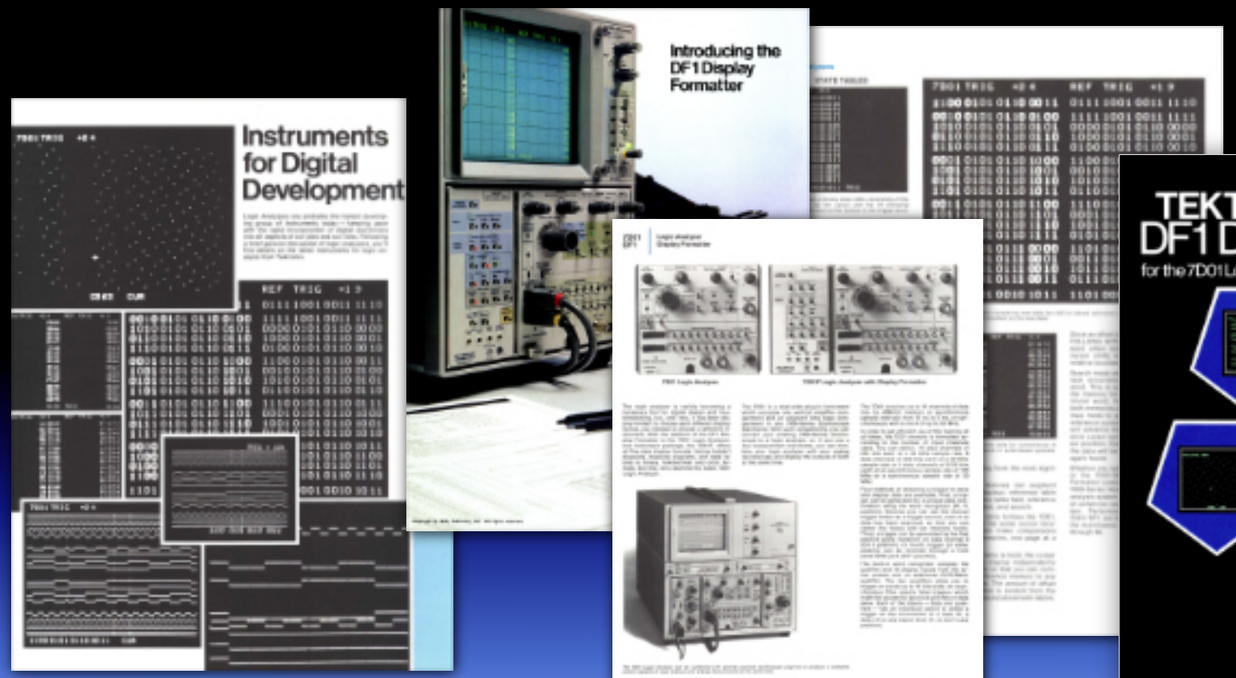
- *the 7603 mainframe: 1,850$*
- *the 7D01F with two P6451 data probes: 4,390$ (more than twice the mainframe price!).*

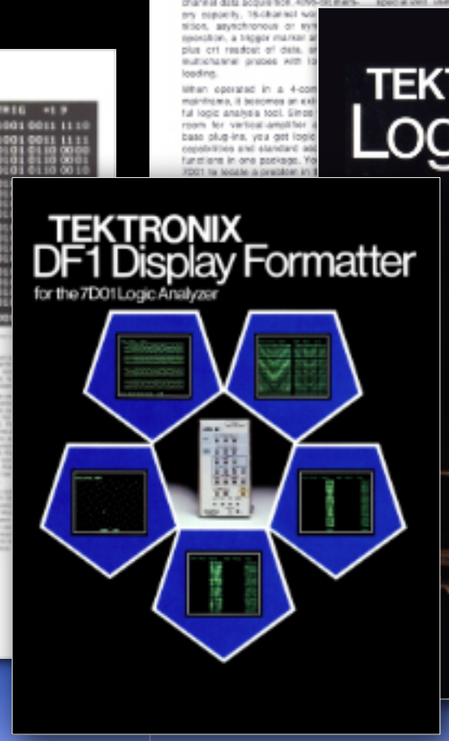
If you were oriented to use the equipment only for logic analysis, you could save 400$ for the mainframe readout system.

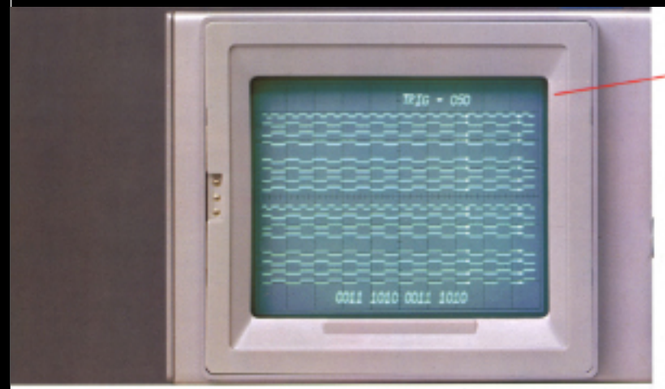
7D01 Explaining the wonders

Tektronix understood that also the documentation should follow the introduction of an equipment so different from traditional oscilloscopes, and that users had to be helped in the digital transition.

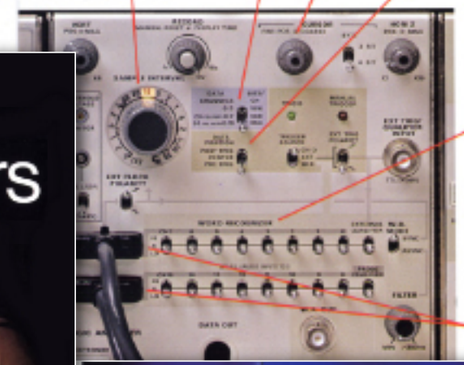
The Tektronix 1977 general catalogue was so not stingy with explanations of the new technologies and two beautiful brochure explaining in simple words the wonders of the new plug-ins was produced. Still today, they can be downloaded from TekWiki.

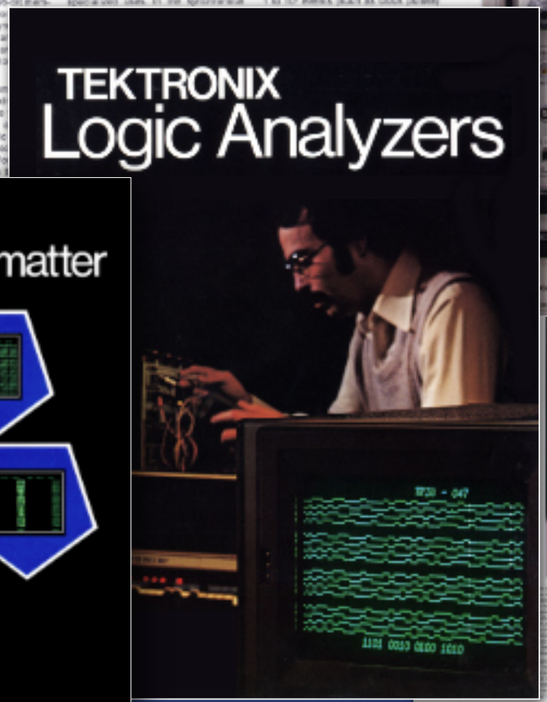






Turn any 7000-Series oscilloscope into a logic analyzer with the 7D01





7D01 What does it do?

With today eyes, 7D01 is substantially a simple device: a "photo camera", capable of taking "shots" of 16 digital inputs in a static RAM. This RAM is large only 512 bytes, so it can only store 256 samples of each input (really 254, that can increase to 508 if you want just to record 8 inputs, or 1,016 for 4 inputs).

The "shutter button" can be pressed automatically, with intervals from 5ms to 10ns or by an external clock up to 50MHz. Data are cyclically stored in memory, until a trigger condition occurs. This allows to introduce in the oscilloscope the concept of pre-trigger. Analog scopes had no way to store what happened before a certain event. Now, when the trigger occurs, we have the stored data and we can investigate them thanks to 7D01. The trigger event can be positioned in the middle of the buffer, at 10% or at 90%, depending of the segment you want to investigate.

Two rows of nice 3-position switches allows to trigger on a specific condition (one, zero or X, don't care).

Data can be presented in various formats, as explained on next pages.

Like a video terminal

When the 7000-Series was introduced, as we noted above, Tektronix defined the capability to show the few readout characters as "possibly the most dramatic feature of the new instruments". *In 1969, only the computers had this striking capability. In 1976, however, the phenomenon of microcomputers had already exploded, and video terminal were no longer an astonishing spectacle.*

At Tektronix, someone, when imagining the 7D01, perhaps understood the new wind and also thought of the large park of 7000-Series already installed. Maybe for reason of time, the 7D01 relied only on the old readout system, but to have a real logic analyzer, something better was necessary. The DF1 was a complete microcomputer, with its own raster video controller, capable of presenting alphanumeric characters, with the quality of a video terminal, and did not use the mainframe readout subsystem.

Without the DF1, the 7D01 could only display data in the timing diagram format, similar to a multi-trace scope (but each channel can represent only high or low states).

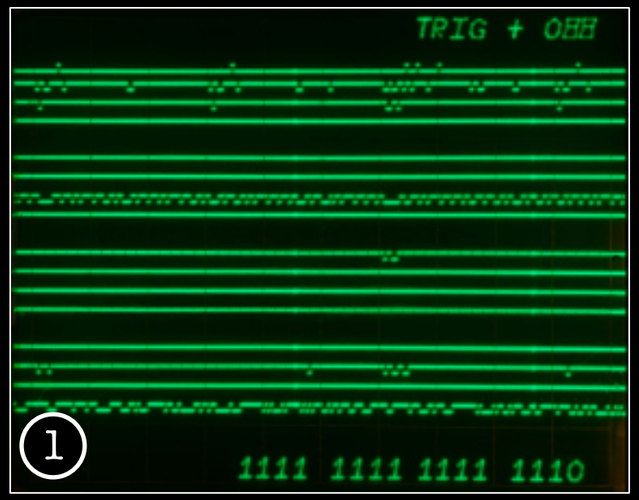
With the DF1, data could be displayed in binary, octal or hexadecimal format, with a better font respect to the old readout system, and also with the capability to highlight the differences with a stored buffer.

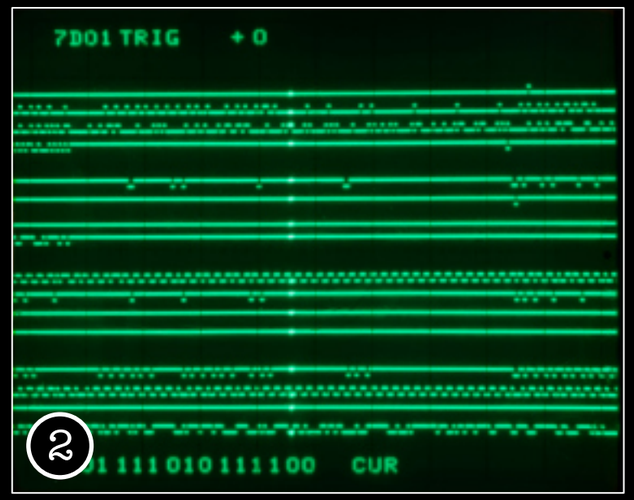
The DF1 gave also another advantage: you could use also a mainframe that did't have the readout subsystem, saving something on the total price. I followed this way: my first 7603 was an "option 1" (i.e. with no readout, strange this Tektronix practice of negative options...), so it was the ideal candidate for the 7D01F.

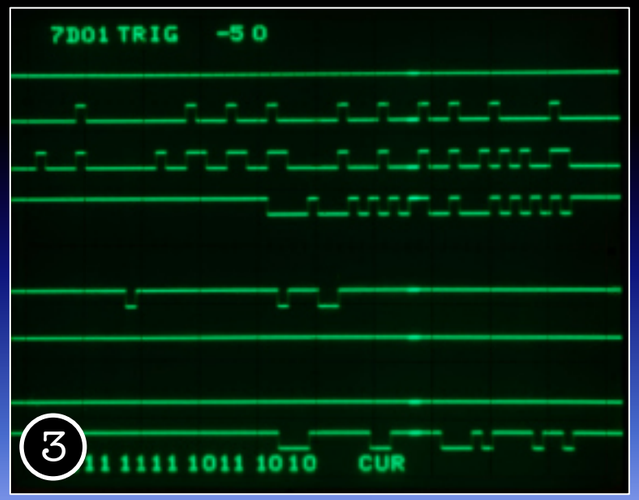
Presentations

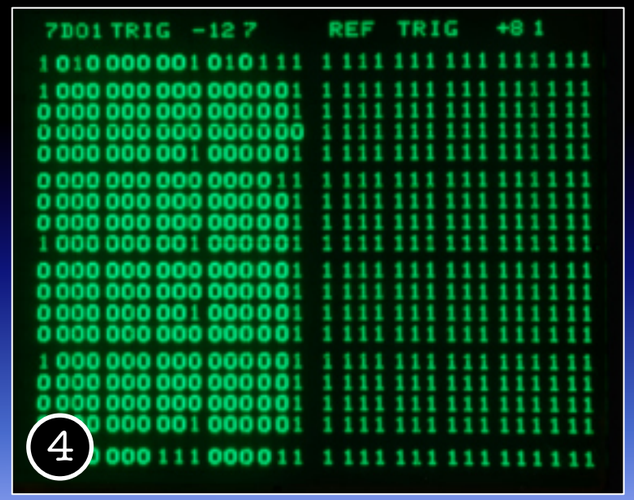
Without the DF1, data can only be displayed in the ❶ timing diagram format, similar to a multi-trace scope (but each channel can represent only hi or low states). Note the "calligraphy" on the screen, similar to the one typical of 7000-Series readout system. DF1 has its own readout system and, with it, you can get the same display but with a better graphic ❷. In ❸ note that you can select 8 channels instead of 16 obtaining a better readability (they can be reduced also to 4). DF1 allows furthermore to add ❹ binary, ❺ octal and hexadecimal data presentation and also to automatically compare the acquired data with a stored buffer, highlighting the differences ❹.

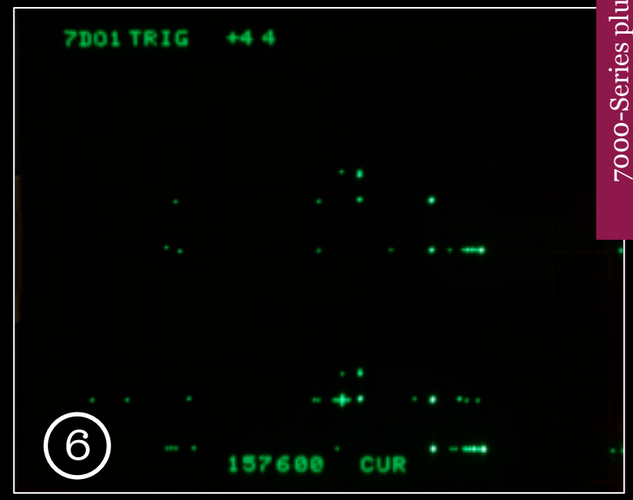
After DF1, a DF2 was produced, that allows also to manage data in ASCII format ❼.











Map presentation

The DF1 provides also three mapping modes, FAST, SLOW, and MANUAL. 64k unique memory locations can be displayed; the most significant half of a hexadecimal word positions it vertically, the least significant half positions it horizontally. Data is scanned with a + symbol in the same order it was entered in memory. The map display ❻ lets you zero in on software problems. In the FAST mode, you watch the + move quickly over the display. Since there's no vector effect, each data word shows up clearly. An experienced operator can learn to tell when there's a fault in the program just from this type of display.

Once the approximate problem area has been identified, you switch to the SLOW mode. The + steps slowly from pot to spot, identifying the word at each location in the CRT readout in hex, octal, or binary. Then, in the MANUAL mode, you position the + at the desired location with the 7D01 cursor control. The problem word is read out at the bottom of the display.

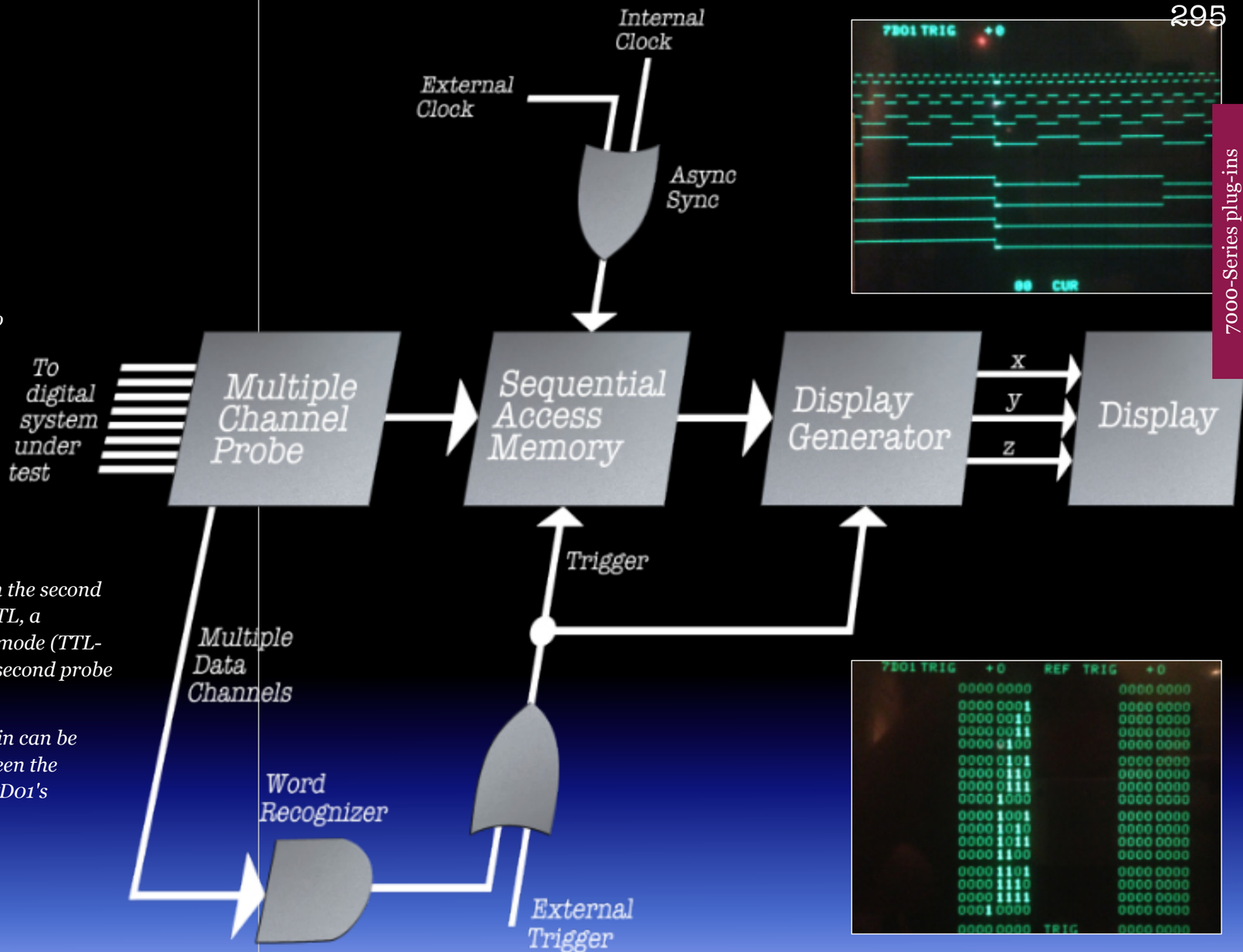
7D01
More details

The 7D01 acquires data asynchronously using an internal clock from 10 ns to 50 ms per sample, or synchronously based on an external clock. A built-in word recognizer can trigger on any combination of the 16 data signals, plus the probe and external qualifier inputs. The recognizer's output is available to trigger an external unit, e.g. when the 7D01 is combined with amplifier and timebase plug-ins in a 4-bay mainframe, giving so the capability to produce mixed digital/analog data presentations. But for this you need to renounce to DF1 and to use a 4-slots mainframe.

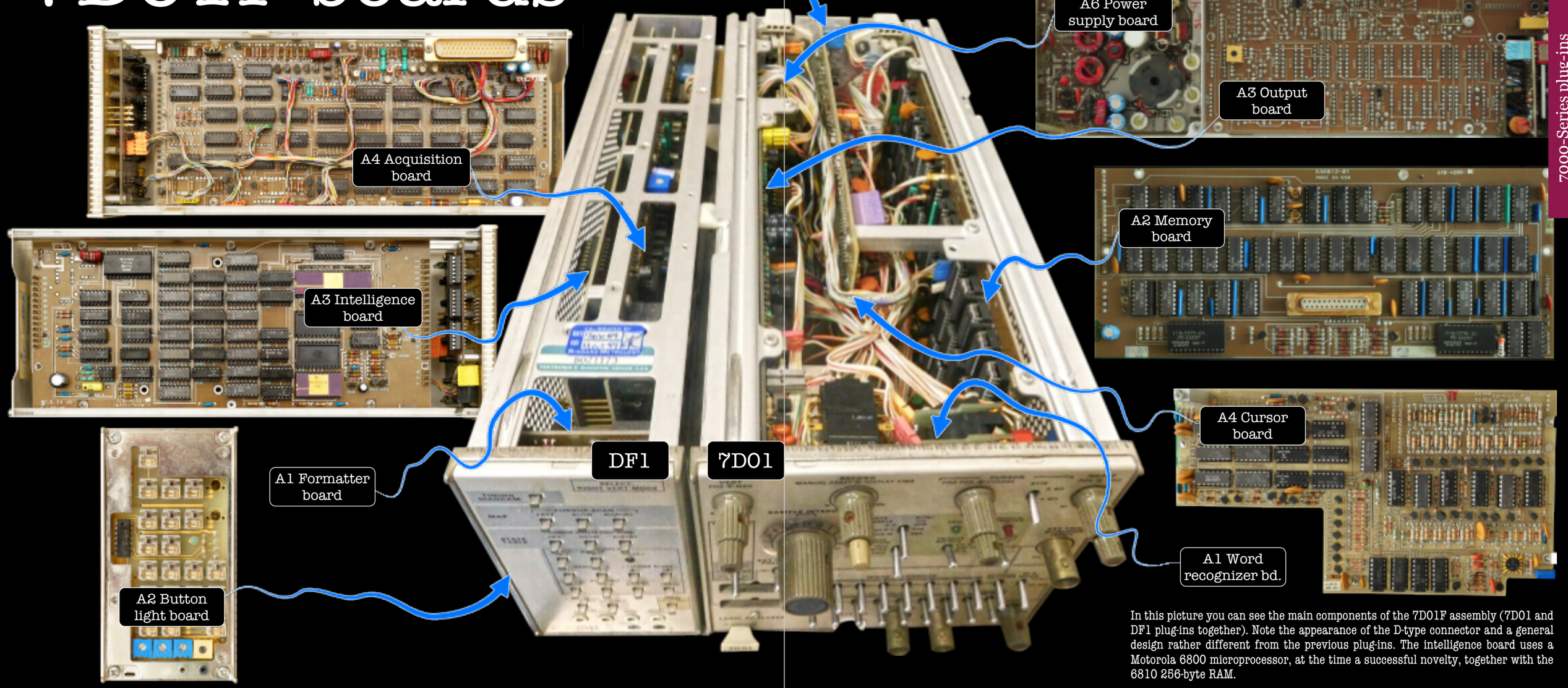
Data are acquired using two P6451 probes (see next pages).

The 9th channel on the first probe can be used as external clock input, that on the second probe as external qualifier. The input logic threshold can be set to 1.4 V for TTL, a screwdriver-adjustable voltage (VAR) between –12 V and +12 V, or a mixed mode (TTL-VAR) where the first probe (0–7, CLK) is set to the variable voltage, and the second probe (9–15, QUAL) to 1.4 V.

There is no internal glitch detector, but a separate DL2 or DL502 latch plug-in can be used to stretch short pulses ≥5 ns to the clock period. The latch plugs in between the P6451 probes and the 7D01's inputs, and receives the sample clock from the 7D01's Store Clock output (from TekWiki).



7D01F boards



In this picture you can see the main components of the 7D01F assembly (7D01 and DF1 plug-ins together). Note the appearance of the D-type connector and a general design rather different from the previous plug-ins. The intelligence board uses a Motorola 6800 microprocessor, at the time a successful novelty, together with the 6810 256-byte RAM.

A computer inside

*I was surprised discovering that inside the 7D01 there was a Motorola **MC6800** microprocessor, that reminds me a lot of things that I though I had forgotten. In 1976, before part of the MC6800 team passed in MOS Technology creating the 6502, that will be the base of the Apple II, the VIC20 etc., the world of us, young engineers, was divided in two parts: the partisans of the **Intel 8080/ Zilog Z-80** and those who supported the **MC6800**. For many reasons, I had been staying almost always in the first group, but, loving also then every new technology, I studied and liked very much the MC6800 as well, like a possible love dream that never became reality.*

*For what I can today understand, the DF1 was one of the first **microprocessor** application in a Tektronix **oscilloscope**. In those days, the evolution was incredibly fast and turbulent. Even if brothers, 7D01 and the subsequent DF1 were absolutely different. The former, also for its need for speed, was based on multi-technology **wired-logic** (discrete, TTL and ECL), whilst the latter presented a typical **microcomputer architecture**, that led to the diffusion on this planet of a new immaterial, wonderful and terrible species: the **software**, a quantum leap for measure instruments and for the entire world.*

Note, in the DF1 Intelligence board (photo on the right), the look of the '70/'80 PCBs, with the first 24 and 40 pins components, amazing at that time. You can glimpse in the photo the characteristic parallel connection of the memory chips, common to almost any design.

P6451 probes

Reading the data

The Tektronix P6451 is an 8+1 channel active logic probe designed for use with various logic analyzers, including 7D01. It presents nine differential ECL signals back to the input section of the analyzer – 8 data channels, plus a 9th channel that is used either as a clock or as a qualifier.

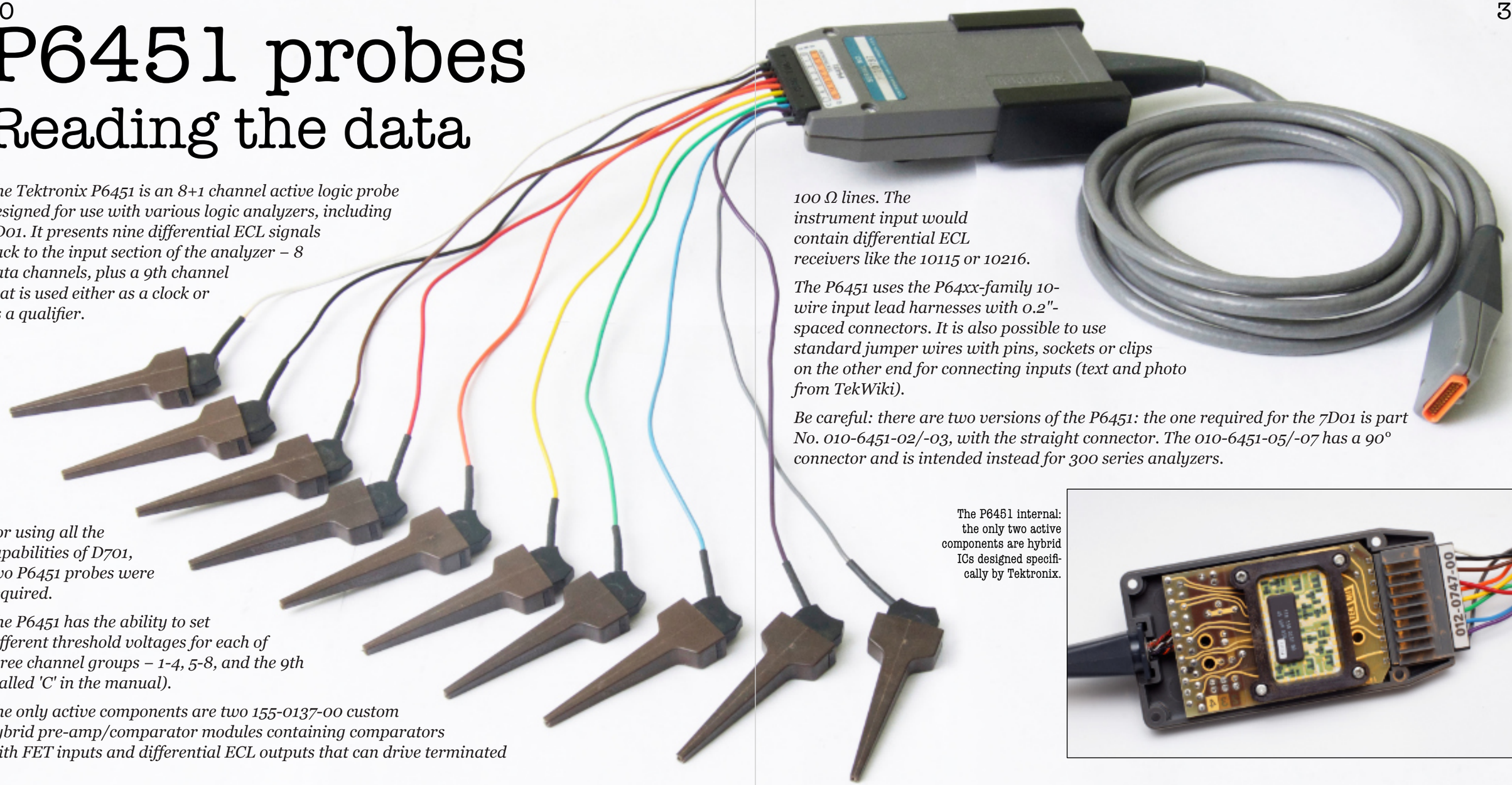
For using all the capabilities of D701, two P6451 probes were required.

The P6451 has the ability to set different threshold voltages for each of three channel groups – 1-4, 5-8, and the 9th (called 'C' in the manual).

The only active components are two 155-0137-00 custom hybrid pre-amp/comparator modules containing comparators with FET inputs and differential ECL outputs that can drive terminated 100 Ω lines. The instrument input would contain differential ECL receivers like the 10115 or 10216.

The P6451 uses the P64xx-family 10-wire input lead harnesses with 0.2"-spaced connectors. It is also possible to use standard jumper wires with pins, sockets or clips on the other end for connecting inputs (text and photo from TekWiki).

Be careful: there are two versions of the P6451: the one required for the 7D01 is part No. 010-6451-02/-03, with the straight connector. The 010-6451-05/-07 has a 90° connector and is intended instead for 300 series analyzers.



The P6451 internal: the only two active components are hybrid ICs designed specifically by Tektronix.

Restoring 7000-Series oscilloscopes

A fantastic activity, in my opinion, or a thoughtless way of wasting time and money, according to my wife.

You will find also some technical notes, derived from my experience.

Restoring Tek scopes

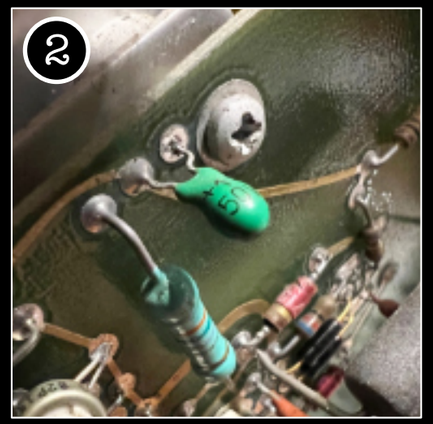
If someone, like me, has something wrong in his head, can find that restoring an old Tektronix scope can be a can an exciting activity. In most of the cases, they can be repaired, because an excellent documentation is available, many spare parts can be found rather easily, and there are many groups and videos that can help you.

Components were, in general, of high quality. Apart from transistor or ICs, the most common faults are the large electrolytic capacitors in the power supply section, that don't become shorted or explode, but just lose all their capacity. Also the Tantalum capacitors, that in Italian are called "drops" for their shape, require often to be replaced (they may short and explode, instead).

It is surprising, for today standards, that they used sockets almost for any semiconductor devices or relays in their boards. It is even more surprising that these sockets are still reliable, if used with a minimum care. They are very useful in locating faults: if you don't want to squeeze your brain to find the wrong transistor, just check all the transistors with a multimeter.

Another frequent cause of problems are the switches, but cleaning them is often enough. See the pages "Repairing switches & push buttons" for some tips regarding their cleaning.

It must be noted that Tektronix, as a true leader should do, produced also a lot of books to broadcast its technology to the world. Many of them are still today very interesting and worth of reading.



❶ These electrolytic capacitors have lost almost all their capacity and were substituted with modern ones in a 7603 oscilloscope.

❷ One of the feared Tantalum capacitors. When they get shorted, can produce more important damages.

❸ One of the books of the Tektronix series, where their technology gets open to the world.

❹ A typical board of a 7000-Series oscilloscope. Note the sockets for the ICs and transistors.

❺ The detail of an almost invisible transistor socket. If you don't know, you can't see them!

The Tektronix colors

The Tektronix blue is very peculiar and does not correspond to any RAL color. I am even not sure that the color has been always the same and that did not change in all these years. I suspect that the old equipment was darker and the newer is lighter. My opinion is based on what I could see in the units I have, but maybe also that the color changed simply in consequence of age.

Some of the my units were so badly reduced that I felt myself forced at least to try to repaint them. What I could do was to get a cabinet in a rather good state (465) and go to a shop specialized for painting, asking them for a special color.

They were very intrigued: nobody asked them a paint for an oscilloscope! At the end they produced a color that was not perfect but rather near to the target I wanted. The cost was not so little (more than 50 euros for 1kg), but the painting is really good quality, much better of any spray.

Should it interest someone, the paint code is Sikkens Rubbol BL Magura Q4.20.38 5051.

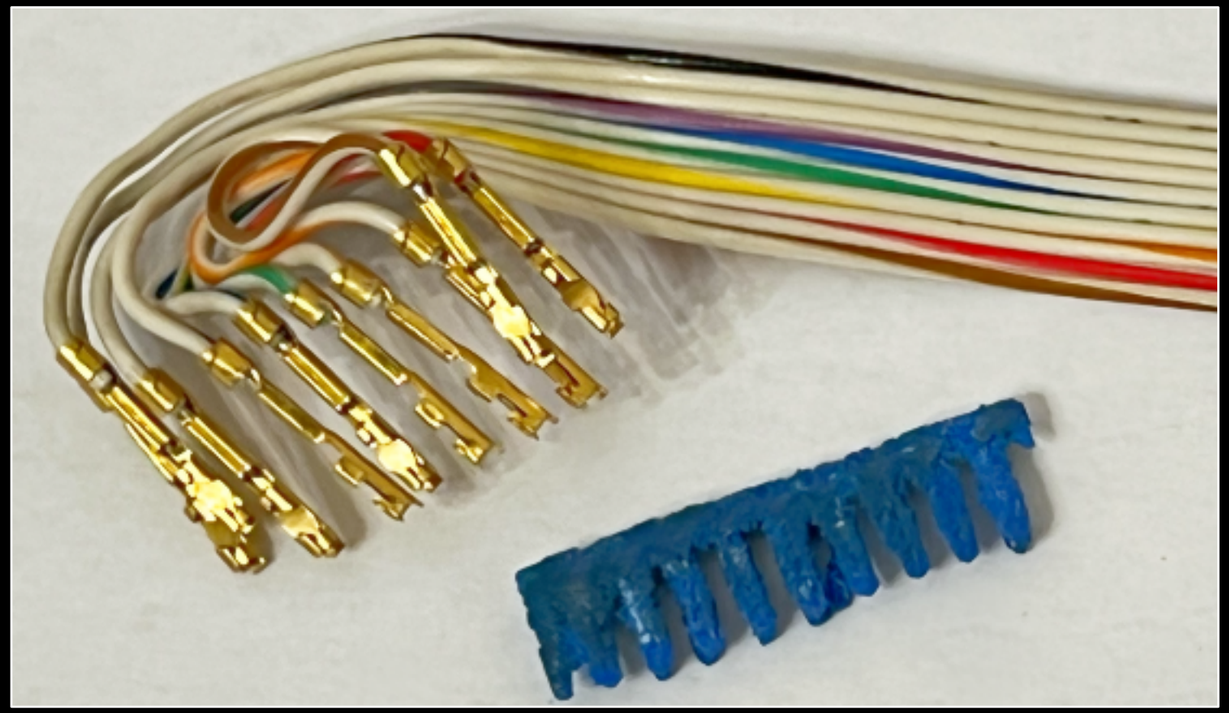
In the photo on the right: the darker ones are the original, the lighter the covers repainted by me.

Plug-in panels

The plug-in panels are generally rather easy to dismount, once you have removed all the knobs (they are simply "snapped" on the body). They are incredibly resistant, and I could even clean them with nitro-diluent without any vanishing of the writings, and, if they are not scratched, can return as new. But few days ago I noted a things that I could not explain. One of my 7B53A had better colors than the others (see the green in the photo below). Why? A change in the production? It seemed rather strange, because I own another 7B53A with almost the same serial number.

Eventually, I think I explained it. The "different" 7B53 is coming from my 7623A, that, according to my reconstruction, spent some decades under a protective cover. So, I checked also the 7A18, coming from the same oscilloscope, and I got the confirmation: also the 7A18 has a far better green in the TRIGGER SOURCE zone (see below). Conclusion: the light contributes to aging....

Here on the right in the circle, another mystery: the vanished writings of a 7B53A. All the panel has the same uniform effect, so it was not a liquid or something like that. Even beneath the transparent crown of the knob, writings are discolored. I was not able to find an explanation.



Also the knobs?

In this picture you can see the color difference between the TIME/DIV knobs of a 7B53, one from a clearly worn by use, the other that probably spent its life in a box.

The UV-rays effect on plastics is very strong, as the restorers of ancient computers well know (photo on the right).

Plastics colors

In my professional life I had the opportunity to collide with plastics. I admit that at first I thought that the matter was easier than it actually is. Just like electronics, plastics also require a lot of technology and experience. A mold for plastic is generally a very large, heavy and complex object and its design must take into account a large number of factors, such as the ability of the material to flow even in the most extreme angles, temperatures, deformations and much more.

Not everyone knows that also the color has a big part in the result. Years ago, we introduced a new product, very important for our company. It was designed by a very famous industrial designer and we developed for it a very tough test plan, to avoid problems in the first units that were going to hit the market. One of its key points was a beautiful glass in the front, glued to the plastic with a super technological adhesive, subject of deep testing. Well: after few days we received complaints about the glass falling apart... We suspected everything: the production process, the temperature, the humidity etc. But in the end we discovered that the cause was... the color! All the tests had been performed with yellow plastic, while the production was in green. It was obtained with a pigment, added to the raw material, not compatible with the adhesive. Still today, while I am writing these notes, I am fighting against the problem of the EN 45545-2 certification (about the safety of the railway sector) of an orange color, that is not present in the black.

All this to say that perhaps also Tektronix had a problem like that. My R7844 S/N B010112 is probably the 12-th unit produced, but, as you can see from the photos, is still today in good shape. So I was surprised when I found some blue plastic debris in the box. Eventually, I found its origin: two connectors of a flat connecting the Readout board. Both connectors were almost totally corroded and crumble. The biggest piece remained is that in the photo here. The other connectors were all good and there was no sign of corrosive liquids. I suspect that the blue plastic pigment caused premature aging of the material (if we can say "premature" after 38 years).

Key labels restoration

If you are going to restore an old 7000-Series oscilloscope, you will learn soon that most of their components are top quality, still after half a century, but some of them were, or are today, very weak. Among them, the labels on the pushbuttons. If you are not very careful, these writings dissolve like snow in the sun, even with light detergents (see the photo below on the left).

So, I find convenient to clean the buttons with a swab, using on the writings just clean water, and then applying a transparent coating, that will protect the characters against wearing and canceling (photo below on the right).

But what can we do when the labels have already been canceled? I have found a possible solution that is not too difficult to put in operation.

First, you need a template. That it is easy, you can download it ready to be printed from my web page (the same where you downloaded this document). If you prefer, you can create them by yourself. I found two different fonts that are very similar to the original ones: BLOGGER SANS MEDIUM *or* UNIVERS CONDENSED.

I used a waterslide decal paper from Hayes, bought on Amazon, that is reasonably priced. In next pages some extra details.

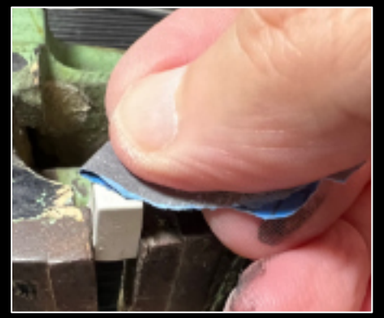
❶ The starting point is a good waterslide decal special paper for the type of printer you have (laser or inkjet). I used this one from Hayes that is easy to find on Amazon.

❷ Then you need a template: you can create it yourself or use this that I prepared (can be downloaded from the web page of this book). Print it on the special paper.

❸ This is a sample starting point. The keys are yellowed and the labels are heavily damaged. The yellow is from the old protective coating, not of the key plastic, good indeed.

❹ Removing the keys is easy and require only a pair of pliers. Just grab them gently and pull pull outwards.

❺ Now you need to clean the keys from the old coating. I use nitro diluent, carefully and quickly because is very aggressive toward plastics.



❻ I suggest to complete the work with a pass of very fine sandpaper, that helps to get a perfect surface for applying the waterslide decal.

❼ Now cut the waterslide decal and put it in the water. They say 30-60 seconds, but being the decals small, few seconds are normally enough.

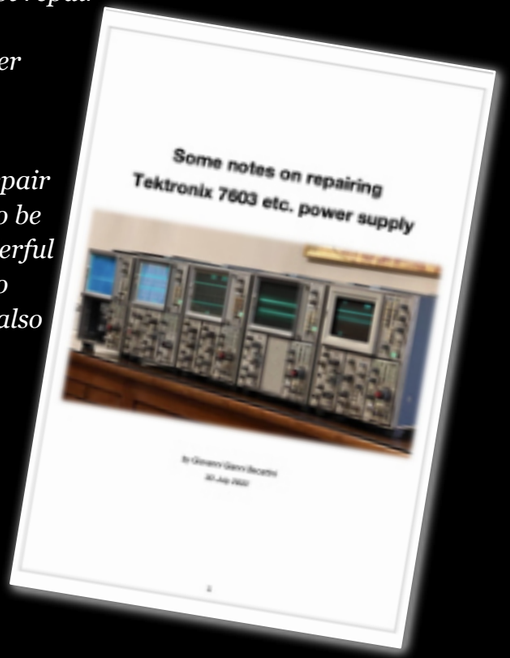
❽ When the decal is ready, gently help it to slide from the paper support to the key and position it correctly. It's simpler than it might seem.

❾ When the decal is dry, apply a transparent coating on the keys and let them dry. Then the keys can be pushed again in their seats. The result is shown on the right.

Repairing the 7603
and other 74/76x3s

The 7603 is not a too complex equipment, and can be repaired with limited means. It is however "intricate", for the large numbers of interconnecting cables. Furthermore, a small mistake in inserting just one connector can lead to a relevant destruction of transistors and ICs.

If today we can preserve these wonderful instruments, we owe it to Tektronix (and TekWiki), which left us a documentation that little equipment, even more modern, has (for example, I own a Lecroy 9361 oscilloscope that felt to the ground and that I cannot repair for having no documentation). Nevertheless, for some operation, the original Tektronix documentation is rather basic.

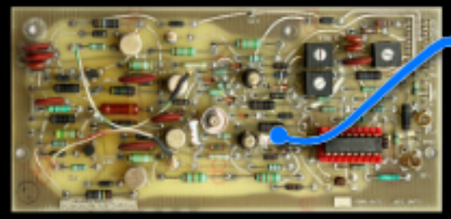


For these reasons, and after some small catastrophes, I decided to add here some information about the 7603 repair and internal wiring, with schemes and photos, hoping to be useful to others who are going to disassemble this wonderful piece of equipment. Almost all of it can be applied also to other similar scopes, like 7613, 7623, 7633 and perhaps also to 7403.

I checked this stuff more and more times, to avoid the responsibility of possible problems, so I trust I have not made too many mistakes. Should you discover any, please write me so that I can correct them.

A separate document, that you can freely download from http://www.k100.biz/parade.htm, describes with more details the 76x3 power supply reparation.

7603 boards location

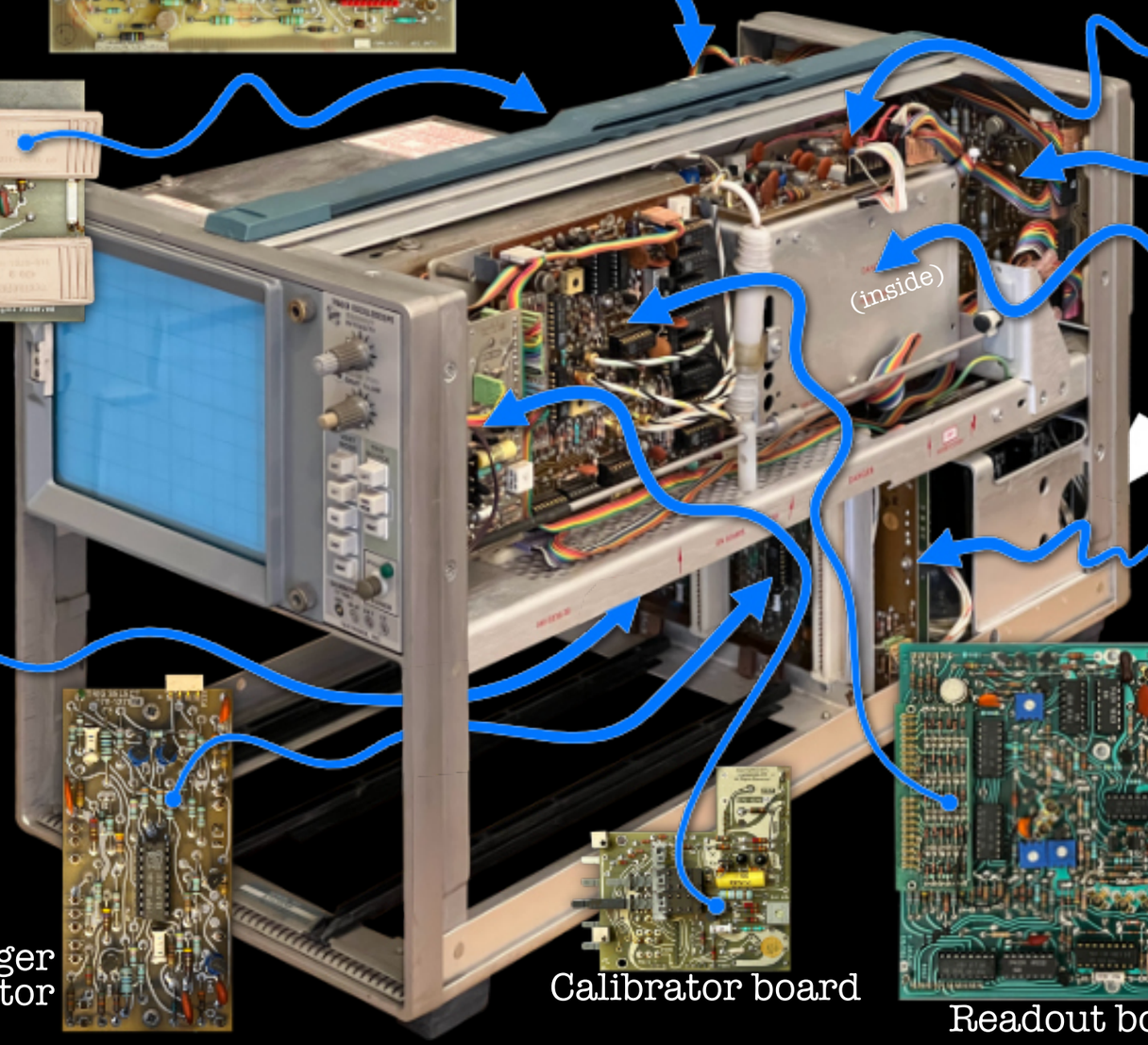


Horizontal amplifier

Vertical amplifier

Vertical interface

Trigger selector



(inside)

Calibrator board

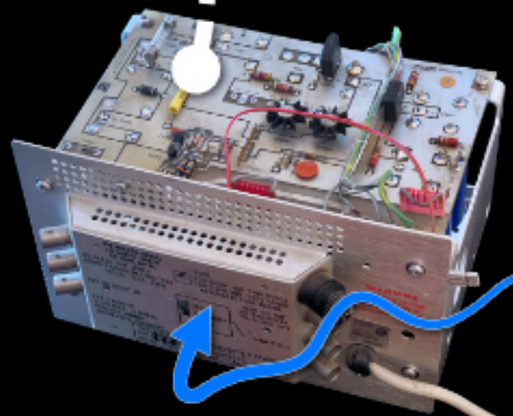
Readout board

Main interface & logic boards not shown

Z-axis amplifier

Low voltage board

High voltage board



Transformer & rectifier module

Signals output board inside

NOTE: boards are not drawn to scale

Overall power wiring

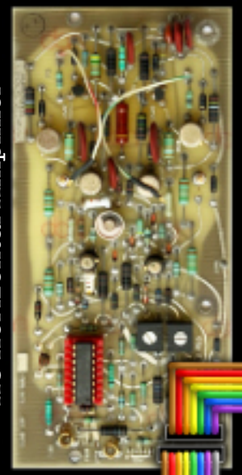
A13 Readout

P2171

5

To P1071
Calibrator board

A6 Horizontal Amplifier

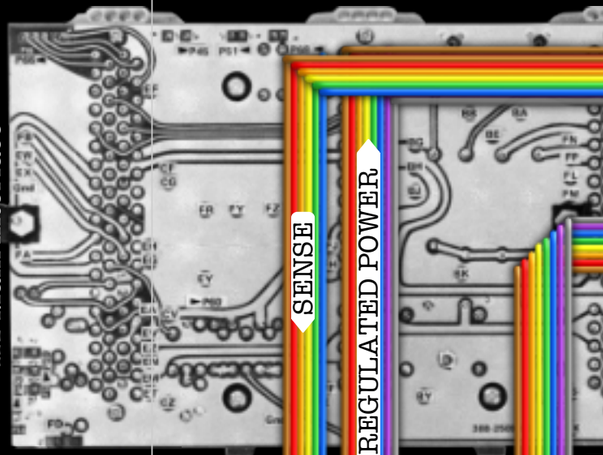


7

P901

A5 Vertical amplifier

A1 Main interface

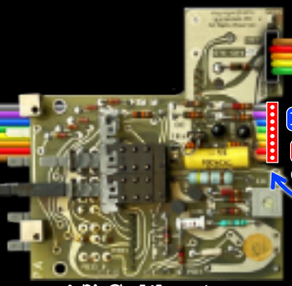


SENSE

REGULATED POWER

P91
brown
P90

8



A7 Calibrator

5
P1071
To P2171
Readout bo

P1092
red
(On back side)

5
P901
brown
P900

8
P962
red

WARNING!
Two pins
remain free

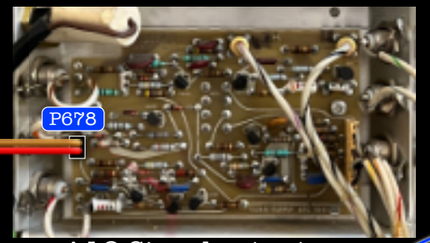
P971
brown

P980

P955

2

P998



P678

A12 Signal output

Line voltage
RED=230V
BROWN=115V

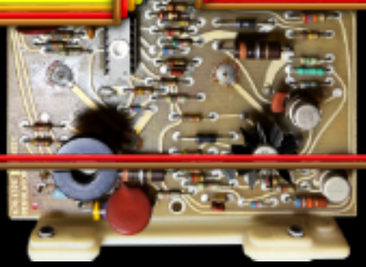
4

P891

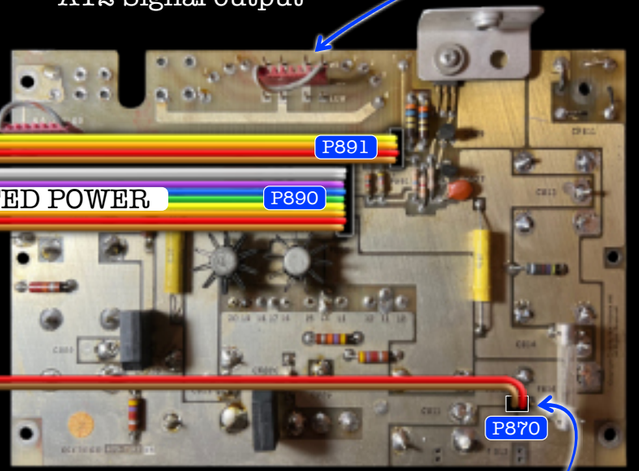
UNREGULATED POWER

P890

10



A11 Low-voltage regulator



A10 Rectifier circuit

P870

WARNING!
One pin
remains free

+15V to power
the HV board
thru Z-axis bd.

8
P1170

P1171
brown

8

P1130

2

8
P1120

A9 High-voltage

A8 Z-axis
amplifier

Mains AC wiring

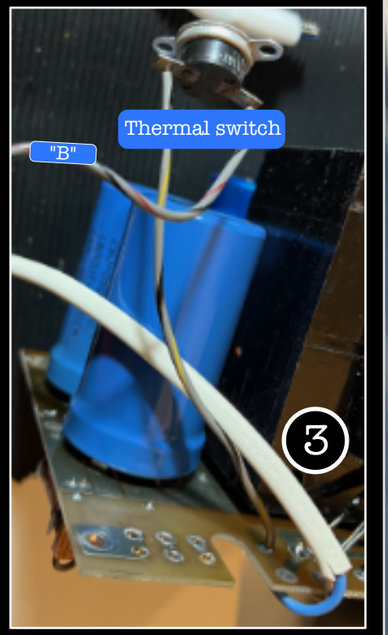
Dismounting the 7603 power supply, requires some wire desoldering. A connector would be desirable, but perhaps costs had been considered.

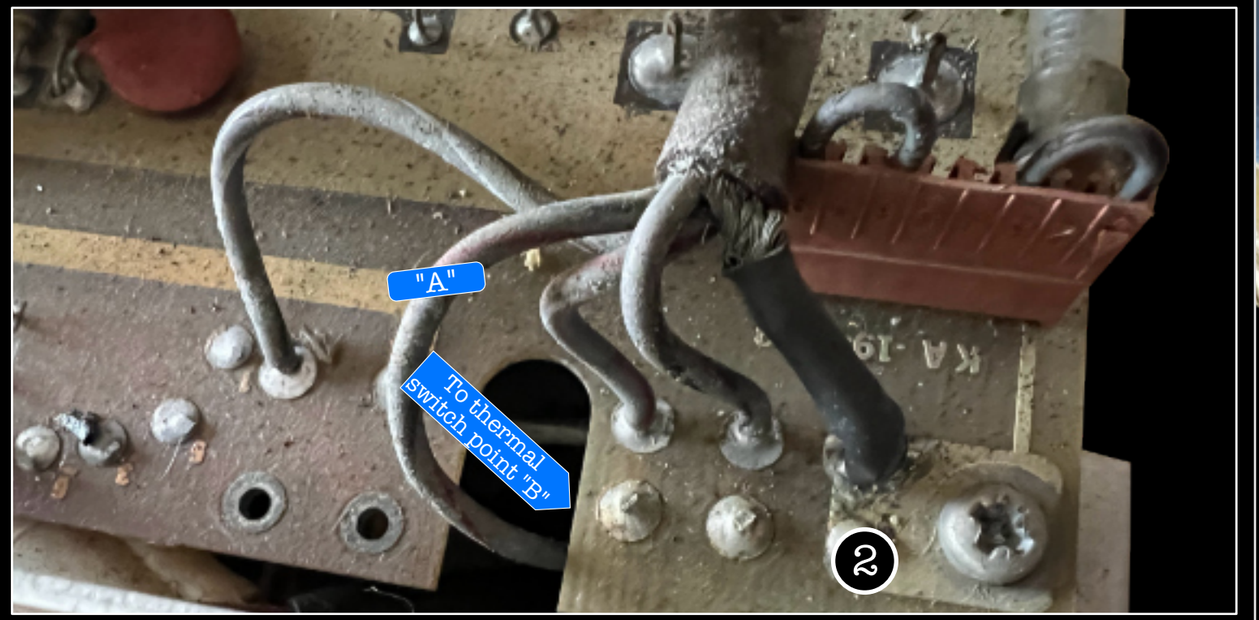
Once you have disconnected the mains cable and the switch cable, you can power directly the transformer @230V soldering the cable between pins 1 and 4 of the transformer.

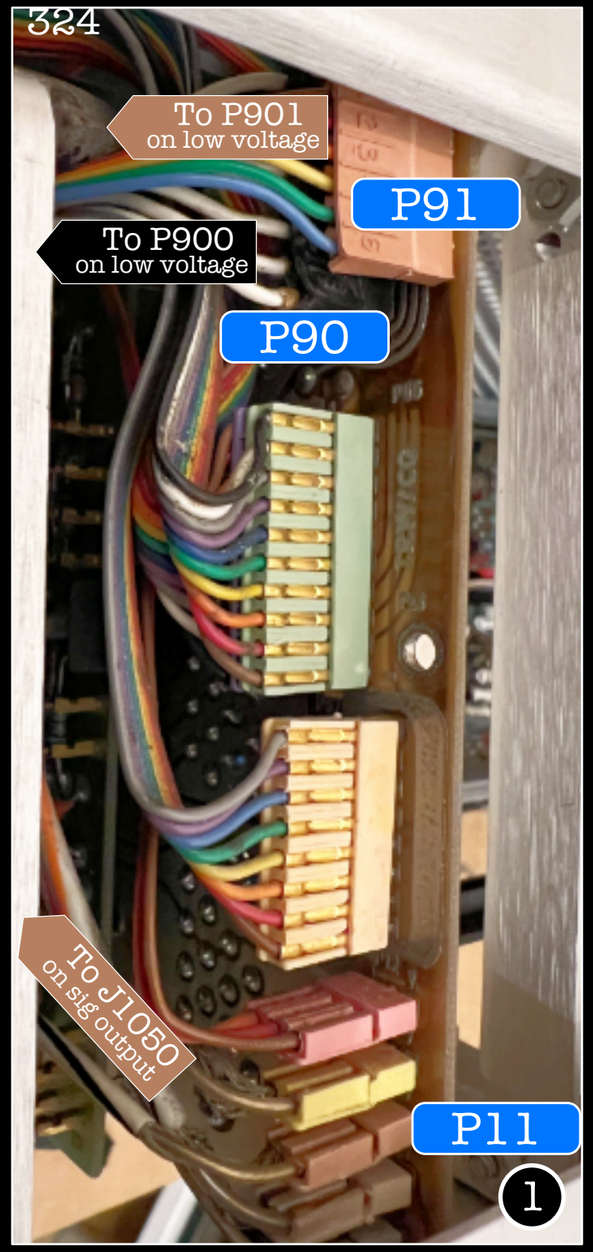
❶ This is the arrival of the mains a.c. wires. The yellow/green is the earth conductor. Note the red jumper, used to select the 230V mains a.c. instead of 115. It can be inserted in three positions (LOW, MEDIUM, HIGH). In Europe, where the mains voltage has been increased from 220 to 230V, the best position is the “HIGH”.

❷ Here you can see the connections of the main ON/OFF switch. A conductor passes thru a thermal switch, the last protection in case of overheating. Note the brown jumper, to be used to replace the red on, if you want to use 115V mains instead of 230V. It is just parked there.

❸ The thermal switch, used to protect the equipment. It must be screwed to the bottom Aluminum plate.





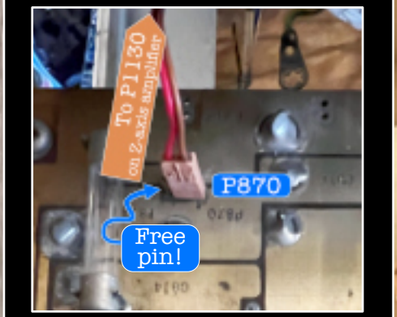


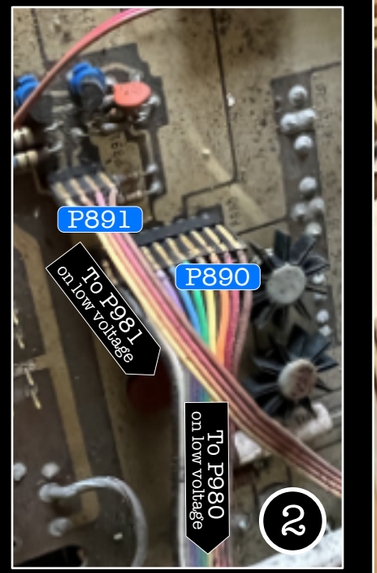
7603 power connectors

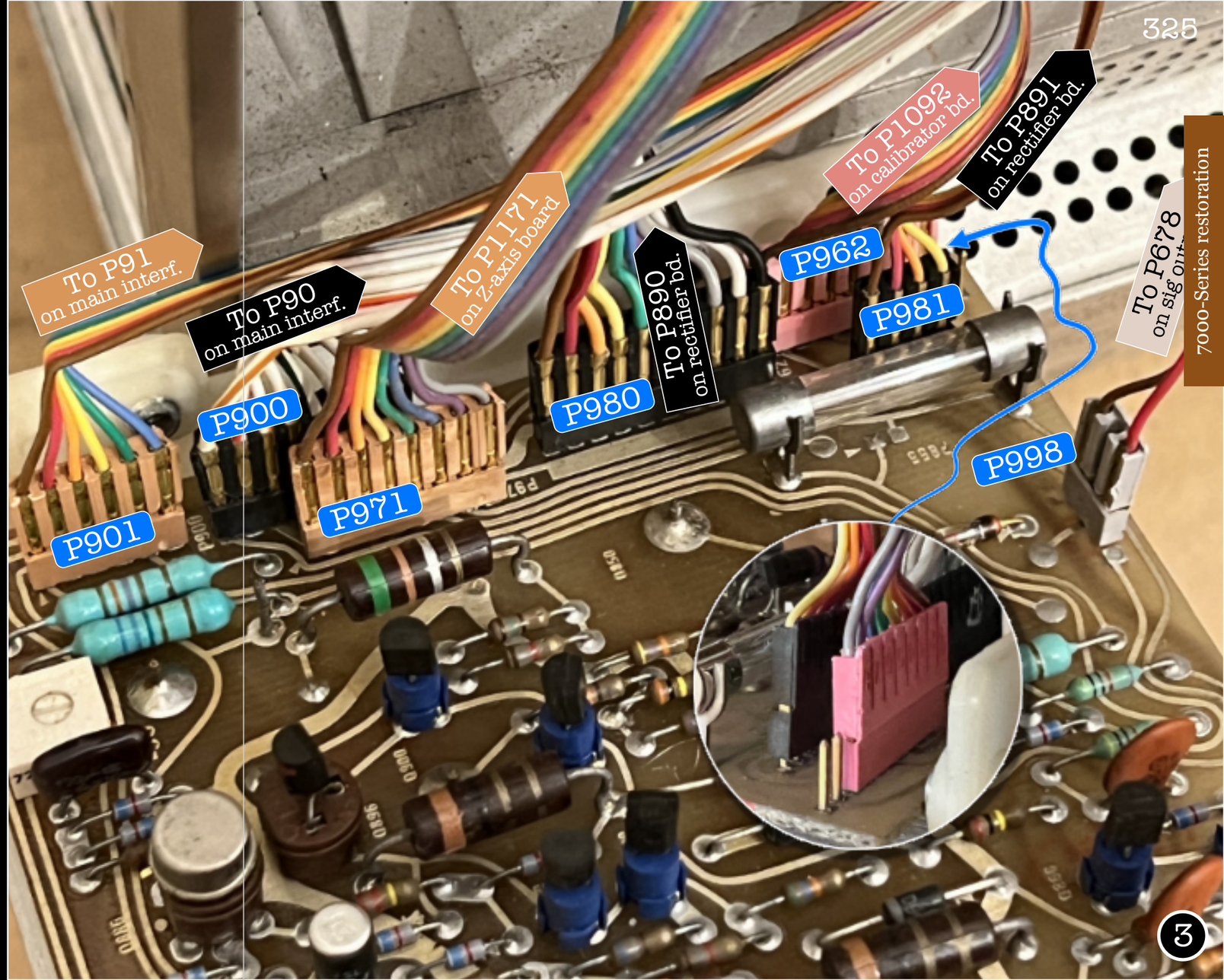
❶ The power-related connectors located on the right side (viewing from the front) of the interface board

❷ ❸ These are the connectors on the rectifier boards. Note the free pin on P870.

❸ The Low Voltage board. Be careful that P962 leaves 2 free pins, as shown in the detail.



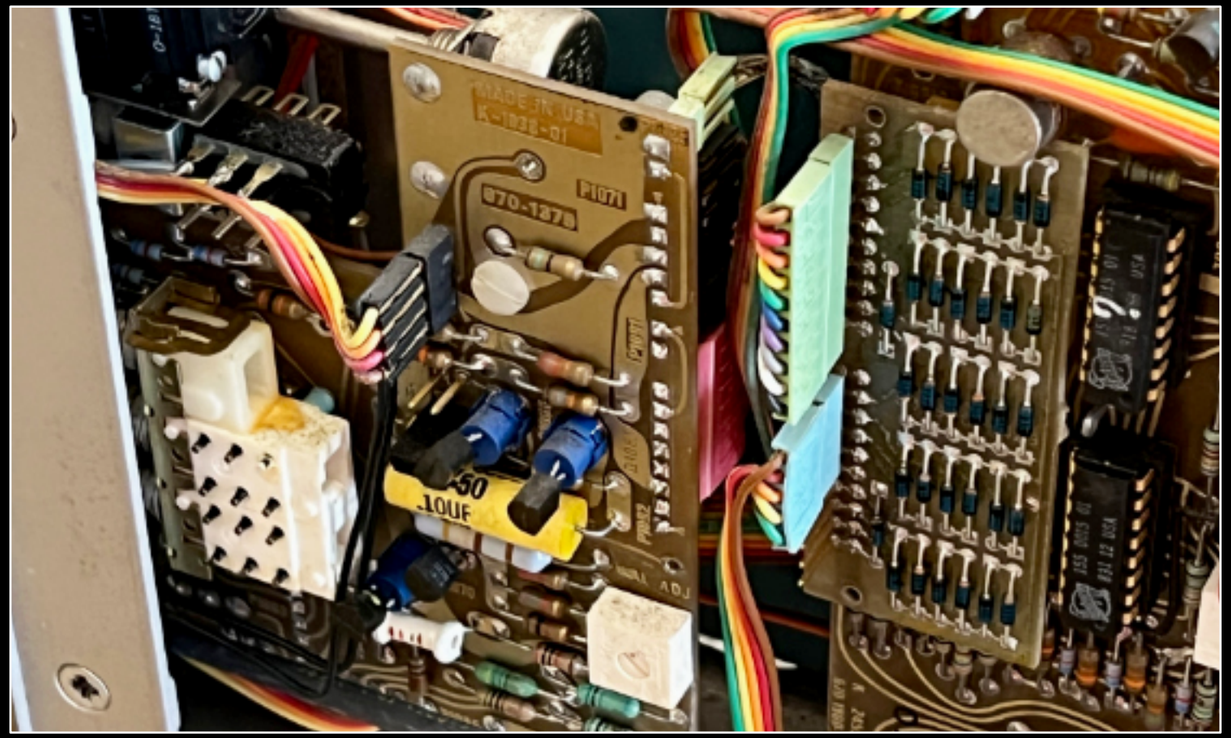


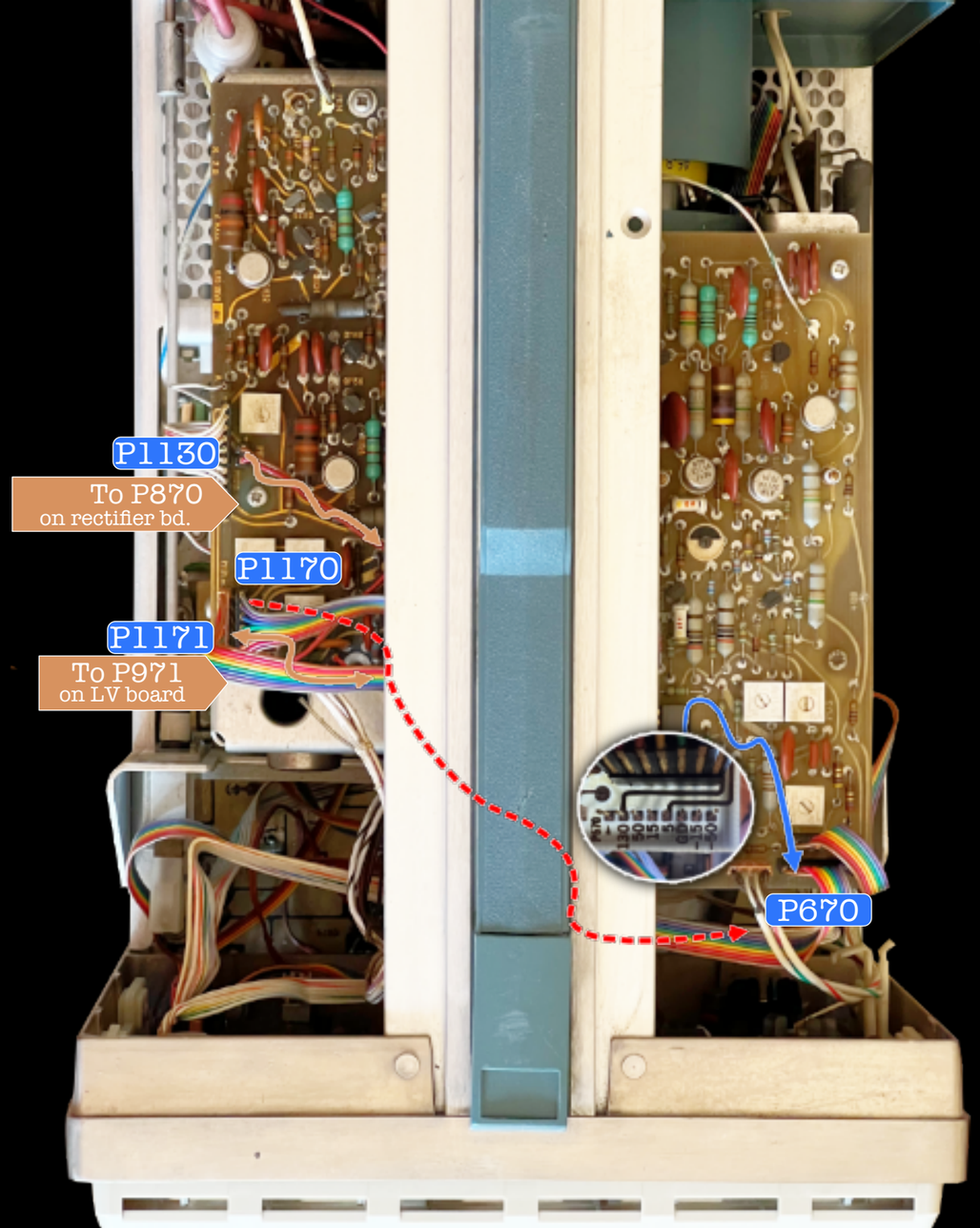


7603 other power connections

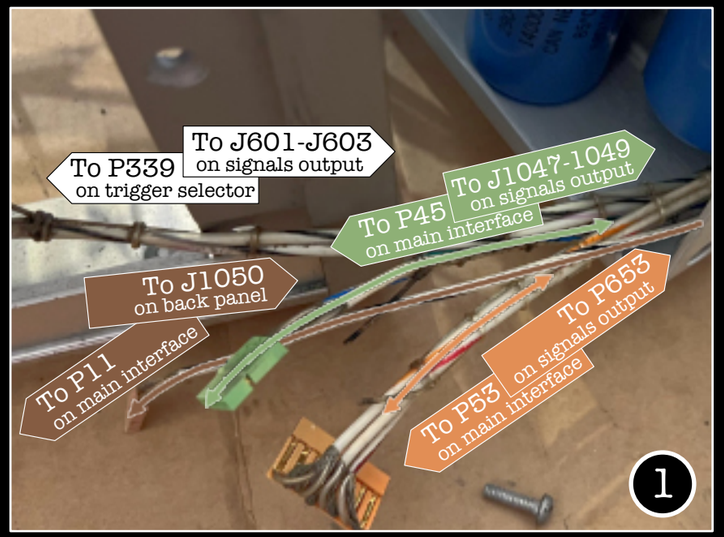
Note that P1171 is the power delivery point from the Low Voltage board to the equipment, so it is a good point to measure the various voltages; but I prefer checking them on P670, because there their name/value are written on the PCB, as shown in the detail (P670 is linked directly to P1171 via P1170, red dotted line in the photo).

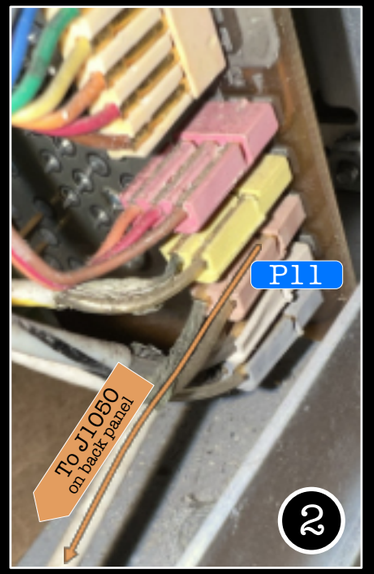
In the photo below, the calibrator board, that can be set to produce a rectangular wave or a continuous voltage, selectable using a jumper. Note the diode array on the readout board, perhaps added later, that protect the lines from the plug-ins to the readout board. One of them, killed by a stupid mistake of mine, saved valuable ICs.

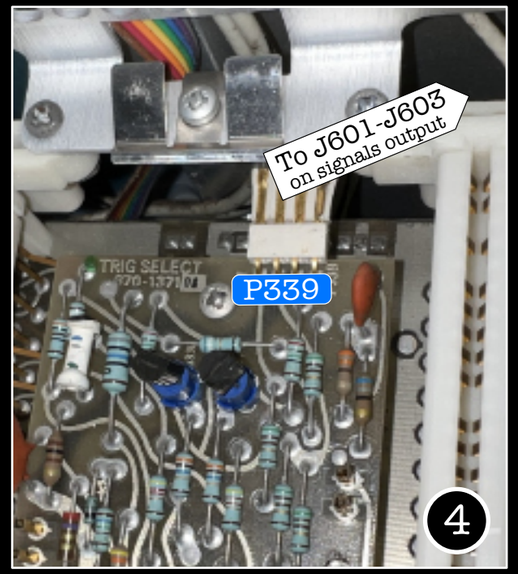




7603 back panel connections







❶ Four signal wires come out from the rectifier module. They lead to the back BNC connectors or to the signals output board. They all must pass thru the rectifier module on the right side (viewing from the front). They are not required to operate the scope, so, during a fault investigation, can be left disconnected. A fifth connector (P998) is used to carry the power to the signals output board and has been already described on the previous page.

❷ WIRE #1, BROWN CONNECTOR: one of the wires coming out from the right side of the rectifier module goes to connector P11 on the left side of the interface board (the one that carries the connectors to the plug-ins).

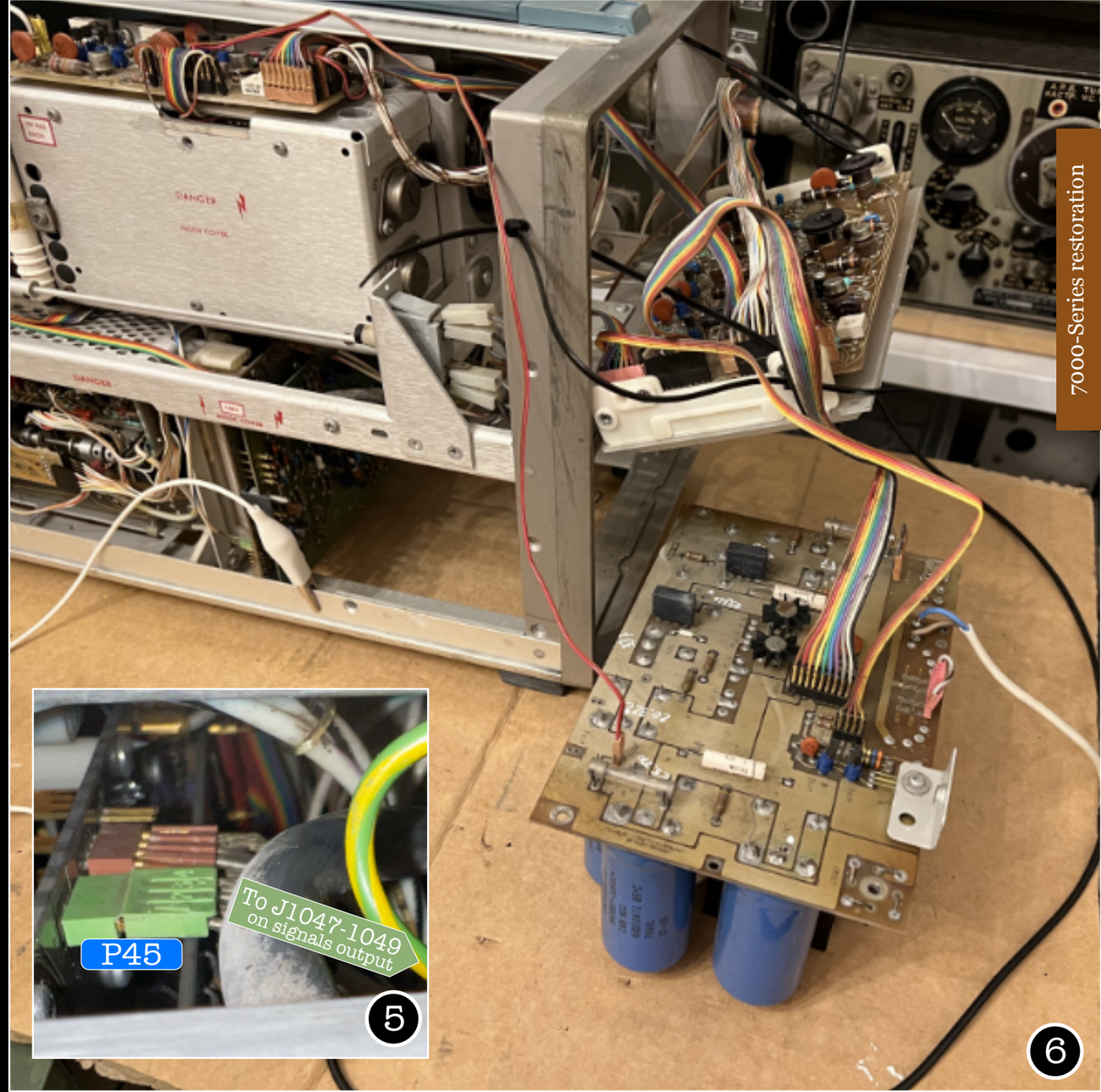
❸ WIRE #2, BROWN CONNECTOR: goes on the interface board, on the lower right side.

❹ WIRE #3, WHITE CONNECTOR: to remove or reinsert this connector, remove the plug-ins and operate from the front of the oscilloscope.

❹ WIRE #3, WHITE CONNECTOR: to remove or reinsert this connector, remove the plug-ins and operate from the front of the oscilloscope.

❺ WIRE #4, GREEN CONNECTOR: this also is not easy to handle: it is located on the upper part of interface board, toward the center of the instrument.

❻ This arrangement connects only the required wires for the power supply, without the links toward the back panel, and makes easier the fault location.



Technical note

Repairing 7603 power supply

Here we report some note on repairs of the 7603 power supply section (and similar). A more detailed note can be downloaded from http://www.k100.biz/parade.htm.

***Caution**: Flat cables were novelties at that time and connectors were not yet polarized/driven. Be very prudent and always check them twice before repowering. All the transistors and the ICs are mounted on almost invisible sockets. Be careful.*

***The circuit.** In the 1969 7904, as we noted, the power supply is partially of the switching type. In 1972 7603, Tek returned to more conventional fully-dissipative design. The power supply section is composed by two modules: A10, rectifier board, mounted on the transformer assembly, and A11, low voltage regulator board. Both of them are rather conventional, but the circuit is complicated by the necessity to create 6 voltages: +50V, -50V, +15V, -15V, +5V, +130V. All of them are mutually dependent and that make things more complex when repairs are needed.*

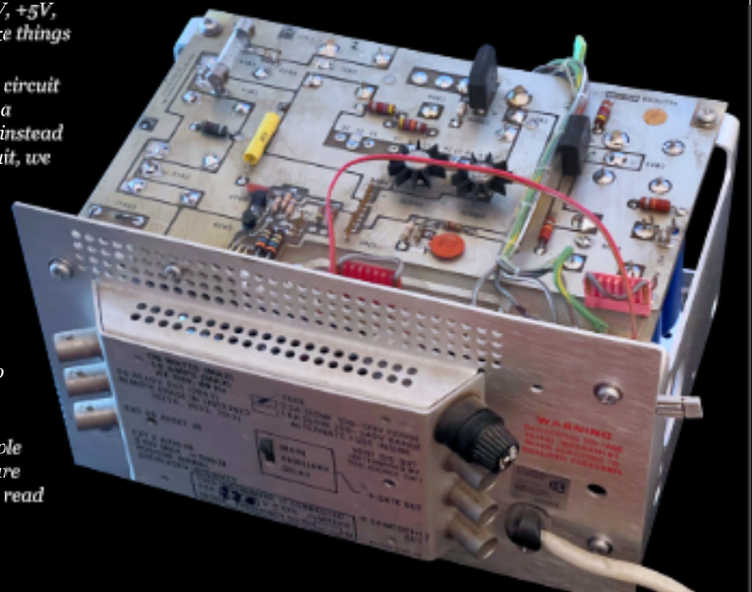
***Sense feedback.** Like any stabilized power supply, this circuit operates as a closed loop, to adjust the output voltage as a function of the load changes. Here we have a difference: instead of reading the voltage at the output of the regulator circuit, we have separated wires to read it at destination, compensating the voltage drop on the main supply wire. Note however that this kind of approach is used only toward the main interface board, perhaps to compensate the differences in the plug-ins absorption, whilst the largest part of the internal circuits doesn't use this feature. All the voltages have also an overload protection, except +130 which uses a fuse. Note that this voltage is generated adding 80V from the transformer to the +50V voltage.*

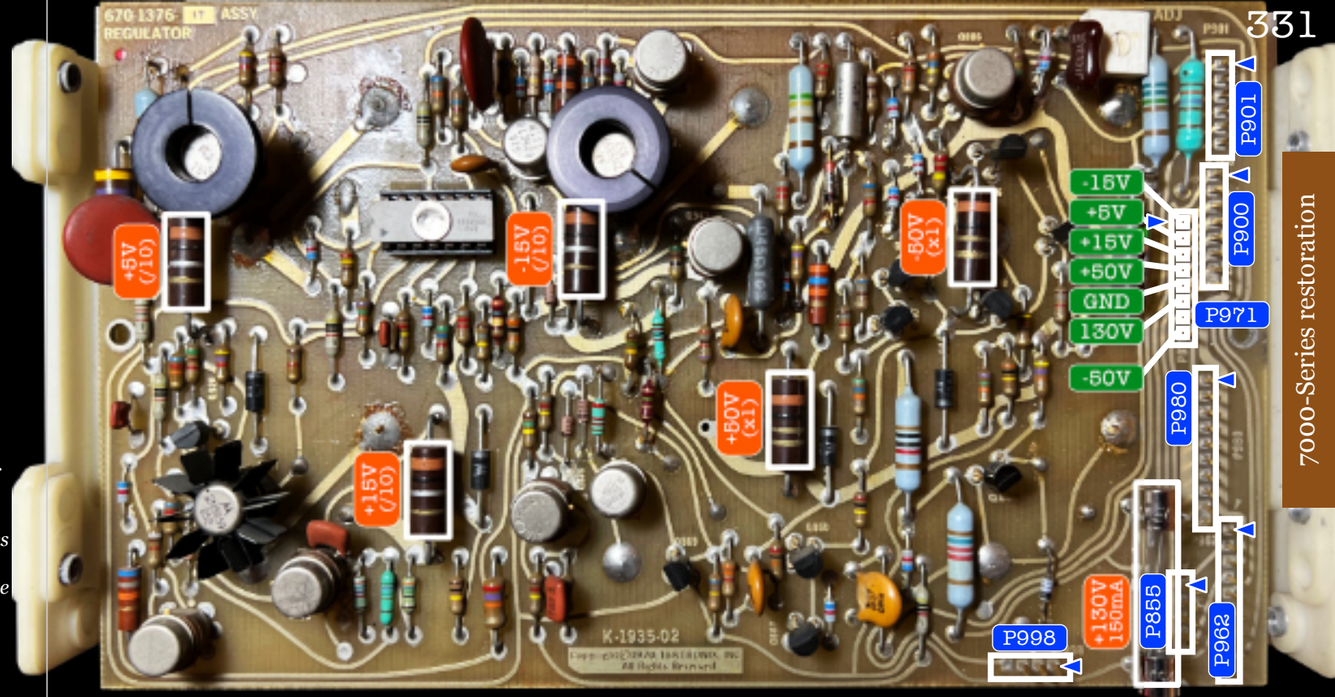
***Measuring the currents.** The resistors designed to be part of the overload protection can also be used as a simple mean to measure the current of each voltage. Just measure the voltage across them. For +15, -15 and +5V, divide the read value by ten (e.g., if you read 1V, the current is 100mA).*

The picture on right helps you in that: you can see the resistors where measure the current and the points for the voltages.

***First power-on approach.** In the case of an old scope that you try to power-up for the first time, different strategies are possible. In the referred note I suggest a possible one.*

***Mainframe wiring**. It is not easy to understand the cables and connectors that go almost everywhere. The drawing on next pages can help you. In general, you have a branch to the main interface board, a branch to the amplifiers (H, V and Z), and a branch to the calibrator and the readout board. The high voltage (HV) board is powered by the unregulated +15V, directly from the rectifier board, thru the Z-axis amplifier.*





***Repairs.** If one or more voltages are wrong, I suggest you stop and check the transformer module. It is highly probable that one or more electrolytic filter capacitors are no longer good. The value of the big electrolytic capacitors should be about the nominal one or greater. You can also check the voltage on the filter with the oscilloscope. If it is pulsating instead of pure DC, capacitors must be replaced.*

***Replacing filter capacitors.** Don't try to unsolder them, it's wasted time. They are big and heavy, and, even if you have a solder large enough, it's likely you will damage the PCB. I found the best way is sawing them away with a common "multifunction tool", is a motor that makes a blade saw to oscillate at high speed.*

Once you cut them, you must clean up the PCB, removing the old terminals. Note that these capacitors have more common pins, connected together. So, when you replace them with modern types that have only two terminals, you must reconnect the PCB pads together. I use a thick silver plated wire to do that. New capacitors are easy to find and are normally much smaller than the original ones, so there are no problems in fitting them. At the end of the soldering work, clean the PCB with a specific product.

***Repairing the LV board.** Repairing the LV board, we have powerful allies: the sockets. What I am suggesting you is the inglorious way: just check any transistor with the VOM, without puzzling too much. It seems slow but could be time saving instead. If you prefer the true man way, you can remount the transformer and try to debug the circuit in the classic way. Considered the interdependencies that make very difficult the analysis, I prefer the coward approach of checking first every semiconductor. By the way: I have found also faults caused by open resistors, not only by transistors.*

Note also that there are two kind of possible problems: a) the LV board is fault and is not able to supply the correct voltage. You can only fix it. b) the LV board is OK, but the load is excessive. In this case, it's useful to perform the current measurement that we discussed before. Check the voltage across the overload resistors. I have no limit value to give you, but it is rather easy to see if a voltage is in the overloaded state. In that case, you have to find out elsewhere the bad guy and not to repair the LV.

Testing the transistors with the VOM. It is very easy, search on the net, you will find lot of videos and tutorials.

***Final tuning.** Adjust R881 on the LV board to set -50V at its exact value. All the other voltages should stay in their nominal value ±0,1V.*

Measuring ripple

Every time that I read something telling "now measure the ripple", I feel myself uncomfortable, because I normally see a lot of noise, that seems to be independent on the ripple itself.

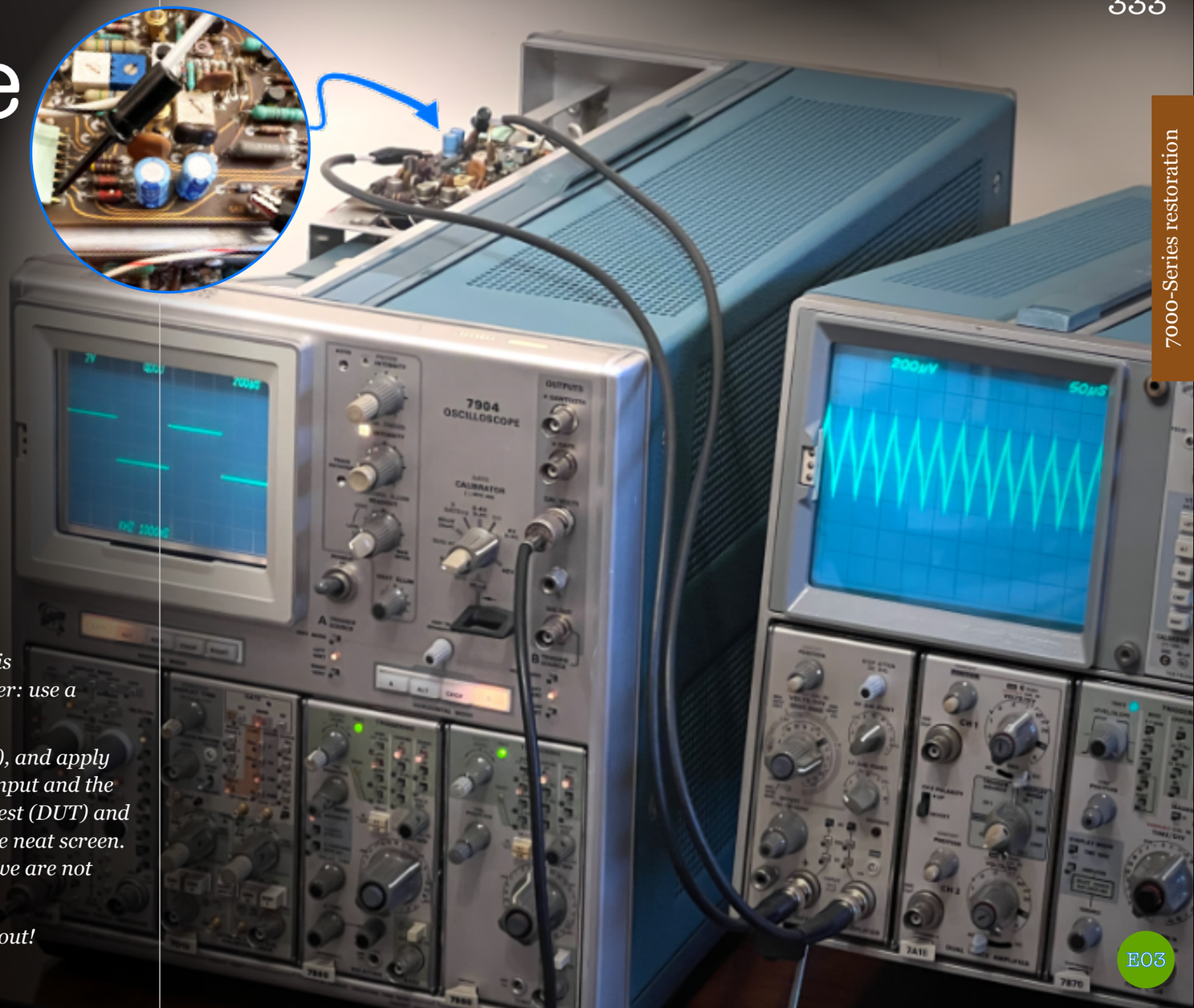
In other respects, measuring the ripple is important when we deal with power supplies, as often happens with Tektronix old stuff. I have not a long experience with them, but for what I learnt in these months, problems with power supply are the most common with that old gear, especially for the "dried" capacitors (I don't know if really something dries, but it is a convincing expression). I found more than a couple of scopes that were neither starting up, because the filter electrolytics had lost almost 100% of their capacity. But what when you are in the middle of the drying process, i.e. the capacitors are not yet dry but on the road to drying? Normally you get a greater ripple, that can produce dysfunctions.

A sign of that is given by readout characters that begin to "dance". Initially, I though that it was some timing problem in the Readout board, but I was wrong: in the 7000-Series, there is no raster, like in a television; if the character positions are unstable, they move accordingly the changing voltage on the screen. If the ripple affects the horizontal and vertical amplifier as well, the effect is that the characters slightly move horizontally and vertically, producing that funny and hated effect. I tried to correct locally the +130V ripple on the horizontal amplifier (adding a capacitor), and character continued oscillating only vertically. But adding capacitors locally is not a good solution, we must go to the root of the problem.

I found a Tektronix technical note specifying the allowed ripple for 7904, 7844 etc. and it is in the 1÷2 mV order. How can I measure that? The article in some way tells also the answer: use a differential vertical amplifier. So I tried with the 7A22 and... wonder, it works!

Just do so: get a BNC/BNC cable, cut it exactly in the middle (to have two identical cables), and apply some form of clip at the free end, forgetting the screen. Now connect one cable at the "+" input and the other at the "-". Connect one of them on the other side to the ground of the Device Under Test (DUT) and the other on the voltage terminal you want to check. Put both channels in AC and enjoy the neat screen. Generally, is better if you limit the amplifier bandwidth with the relative knob, normally we are not interested in the high frequency noise.

In the photo: a 7603 checks the ripple to a 7904. Look at the marvelous 200µV in the readout!



Fans, 400Hz & noise

Looking at many equipment labels, I often asked myself: "why 400 Hz?" 400 Hz power networks have become the standard for weapon systems, aerospace, and aircraft industries across the world, because the 400 Hz equipment is lightweight, reliable, and offers high power capability. As a consequence of it, airports, hangars, and ships that carry aircrafts have 400 Hz power systems.

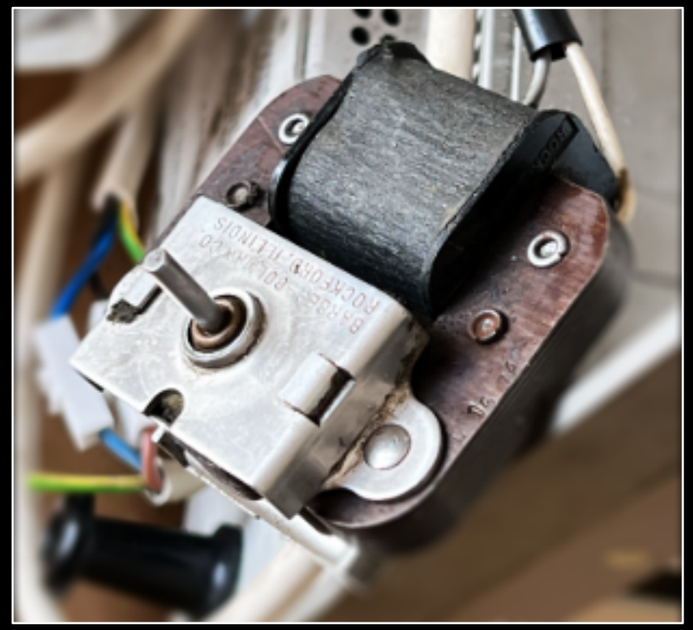
Continuing with questions addressed to myself, I noted that some 7000-series oscilloscopes have a label stating 50-60Hz, but other have 50-440 Hz (photo below). Why, considered that their power supply are almost identical?

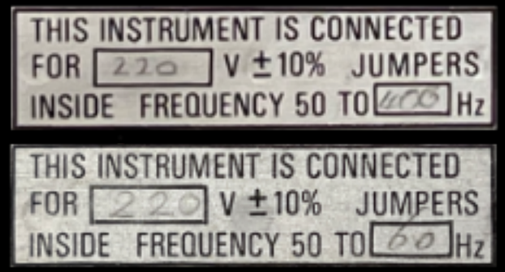
The reply came reading the 7844 oscilloscope description in Tekscope 6-1974:

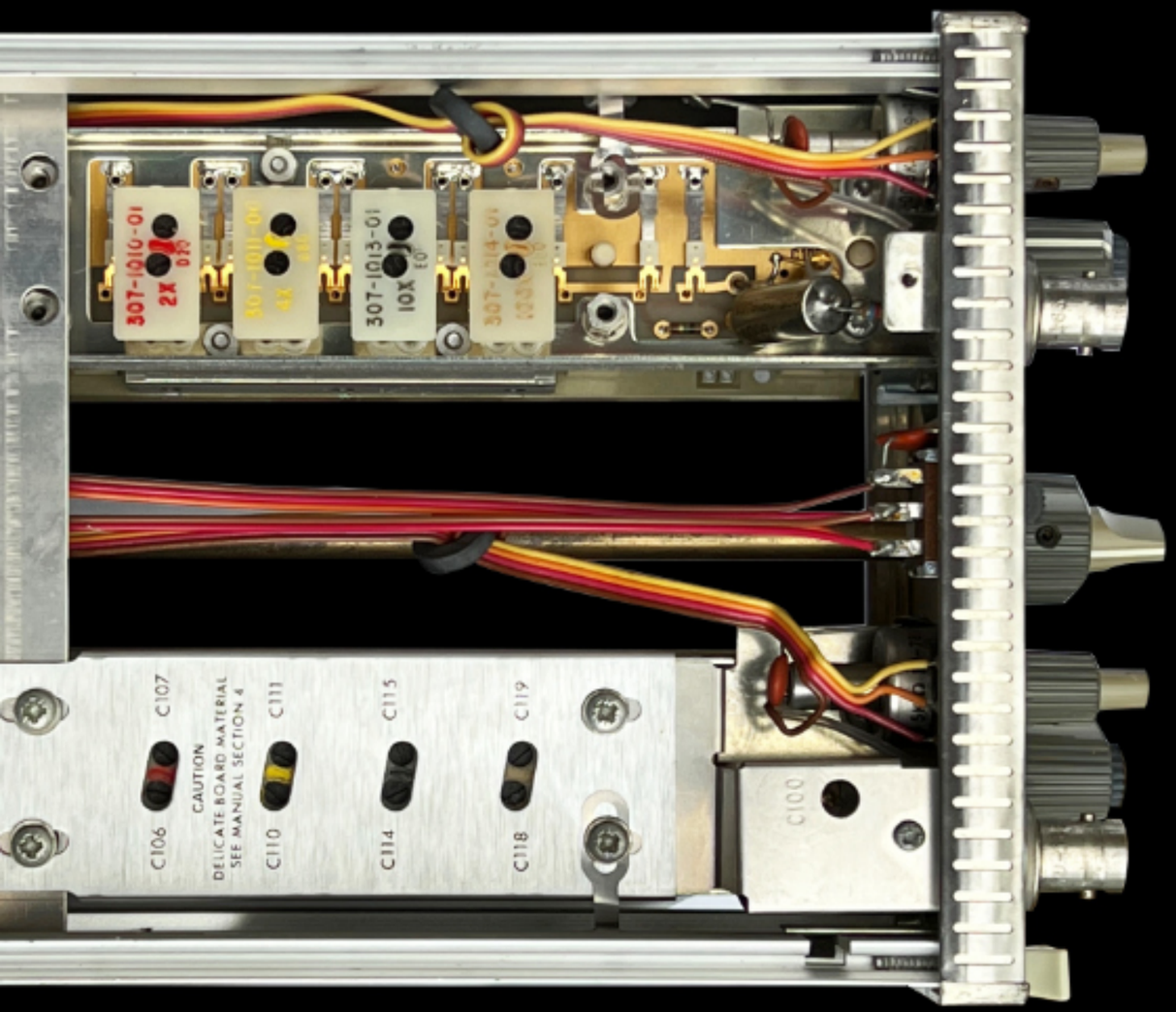
Because the 7844 has a DC fan it will operate from a power line having a frequency from 48 Hz to 440 Hz.

So I checked my electronic friends: limited to 60 Hz are those with the fan! The fan is the limiting factor, because, in most oscilloscopes, when present, the fan is based on a synchronous motor, in which the rotation of the shaft is synchronized with the frequency of the a.c. supply voltage. These inexpensive and durable devices can accept the 50 or 60 Hz, but are not able to work at 440 Hz.

I said durable, and they seem to be so, but the fan of my 7633 had start becoming a little noisy, so I dismounted it, as shown here. The fan ball bearings are sealed, and it is not possible to overhaul them. So I limited cleaning up everything and applying some oil drops. The result is good and the noise disappeared. Not too bad, for a motor that has probably been running for tens of years.




THIS INSTRUMENT IS CONNECTED
FOR 220 V ±10% JUMPERS
INSIDE FREQUENCY 50 TO 400 Hz
THIS INSTRUMENT IS CONNECTED
FOR 220 V ±10% JUMPERS
INSIDE FREQUENCY 50 TO 60 Hz



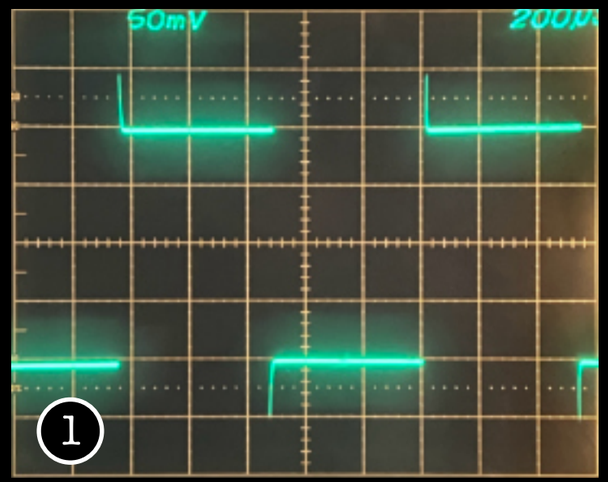
In this photo: the 7A18 attenuators are very similar, if not identical, to other plug-in amplifiers. The one above has the aluminum screen removed, to show the four blocks inside (2X, 4X, 10X and 100X). They can be easily removed just pulling. In this way you can also clean the underlying switch contacts.

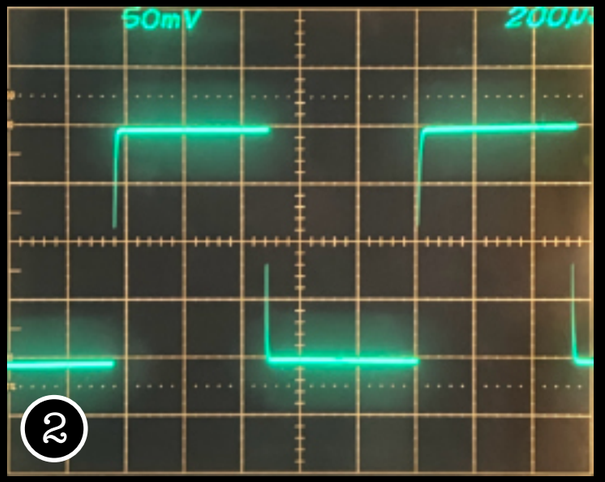
Attenuators calibration

The attenuator calibration is required so that a rectangular wave is displayed on the screen as... a rectangular wave, without deformations, such as overshoots (photo ❶ below) or dampings (photo ❷ below).

To do that, you mainly need a good signal generator, providing a 1kHz rectangular wave, and a tuning plastic screwdriver. Tektronix recommend a series of instruments and adapters but for me is enough the signal generator, with 50 ohm output impedance and a 50 ohm terminator on the oscilloscope side.

I state that the procedure that I am going to describe is not entirely my own work, I found it on EEVBlog and elsewhere on the Internet, and I took the liberty of reformulating it with some small changes, after having tested it, even to adapt to 7A18 that, for its simplicity, I will take it as an example. Most of this information is good also for other vertical amplifiers.





Attenuator description

The attenuator is composed by 4 cascaded attenuator blocks: X100, X10, X4 and X2. Each block is a separate, pre-built, socket-mounted module, that can be easily dismounted and/or replaced (see photo on previous page). Each block has furthermore two capacitive trimmers, one said "Square corners" and the other "Flat top". The calibration operation consists in adjusting these trimmers.

The various knob ranges are obtained by mean of a combination of these blocks, according the table below; only two blocks are used at maximum. Note that in 5mV range the attenuator is bypassed, and the signal input is linked directly to the amplifier. In other plug-ins, such as 7A16 and 7A26, also the 10mV range bypasses the attenuator, and the amplification factor of the amplifier is divided by two (10mV) or not (5mV). As stated above, the following notes are for 7A18.

Attenuator, calibration

The 5mV range does not go through the attenuator and it's a direct link from input to the first stage of the vertical amplifier. Its calibration cap (C100) cannot be adjusted without a plug-in extender, because it remain hidden by the oscilloscope frame. Luckily, it normally does not require adjustment.

For the calibration, if you follow sequentially the adjustment table reported by the manual, you'll spend a frustrating lot of time trying to get the 1KHz square to look decent across all ranges, and probably the result is still not good.

	X100	X10	X4	X2	Corner	Top
5mV						
10mV				X	C106	C107
20mV			X		C110	C111
50mV		X			C114	C115
0.1V		X		X		
0.2V		X	X			
0.5V	X				C118	C119
1V	X			X		
2V	X		X			
5V	X	X				

Suggested procedure

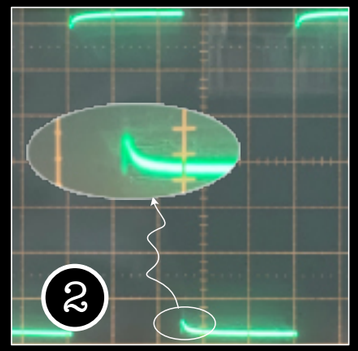
My suggestion is to proceed as follows:

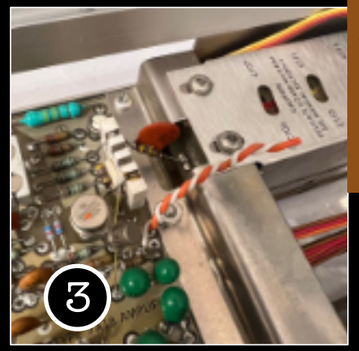
- *roughly adjust the four adjustable ranges (10, 20, 50mV, 0.5V);*
- *let's take the 10mV block adjustment as an example. The .1V range uses it as well (see the table); whatever adjustments you make to 10mV range, it will affect the .1V range. So: set to 10mV/div and adjust*

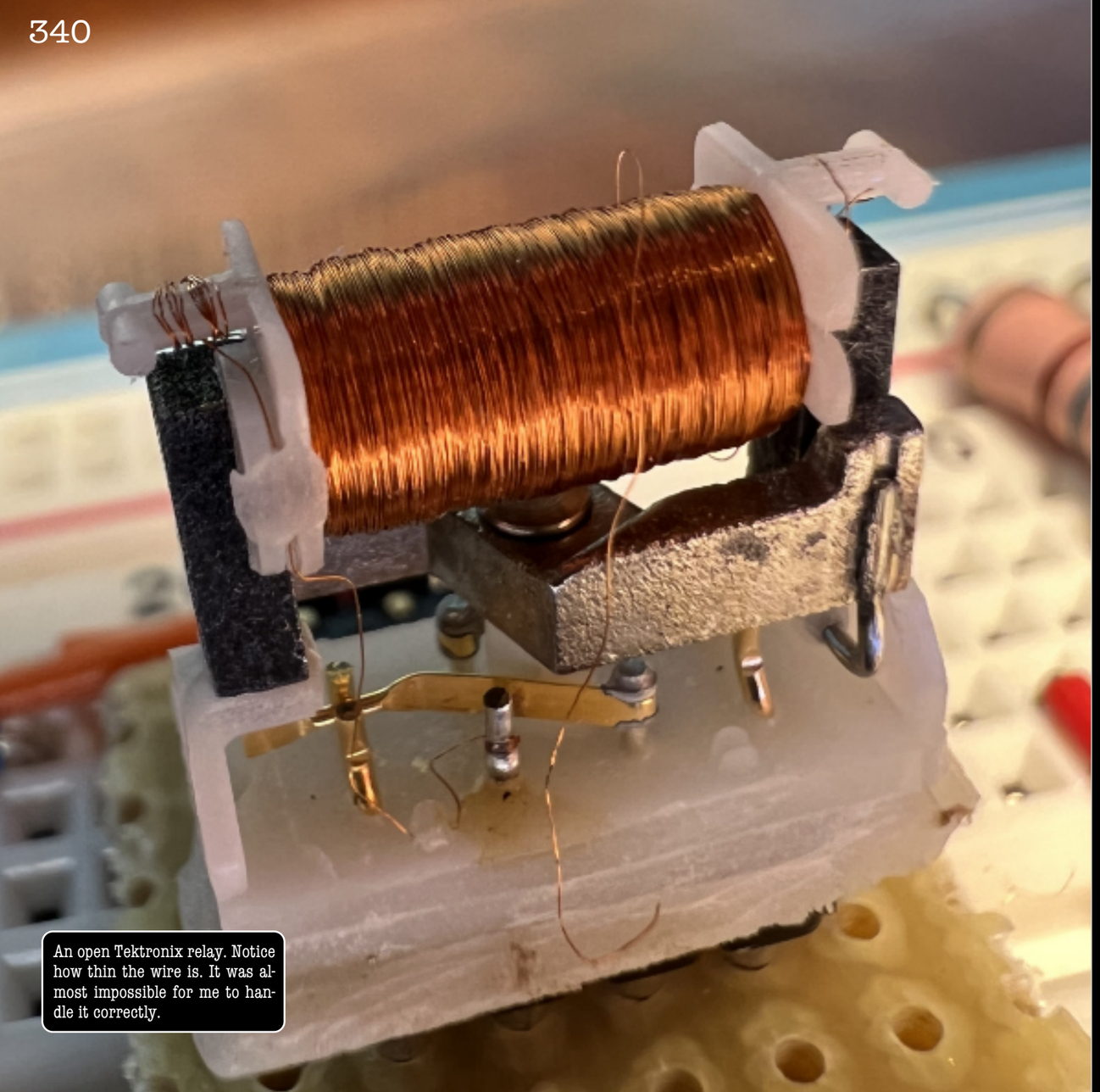
C106 for square corner, but do not touch C107. Switch to .1V and adjust C107 for best waveform, always adjusting the signal generator to show about 6 divisions. Do not adjust C106. Iterate the process, if needed.

- *follow the same procedure with 20mV/.2V ranges and 50mV/5V ranges. Adjust the square corner cap only on the mV range and the flat top cap only on the V range.*
- *in the 0.5V range you can adjust both and it should be OK.*

C221/412 capacitors: I wish to recall your attention on a very small capacitor (C212, 1.8pF on channel 1, C412 on channel 2, photo ❶) that gives a great contribute to the compensation. On a 7A18, I had the strange problem I show you in photo ❷: a small curl that I was not able to fix adjusting the trimmers. I just desoldered one side of it and the shape became perfect. But it is important and cannot be simply removed, because it contribute to the stability of the compensation when you switch to a different range. As suggested on http://wunderkis.de/tek-7/, I tried to replace it with a short piece of twisted wire (photo ❸) and I got very good results. Now I replaced C212 with the correct capacitor and everything is now OK.







An open Tektronix relay. Notice how thin the wire is. It was almost impossible for me to handle it correctly.

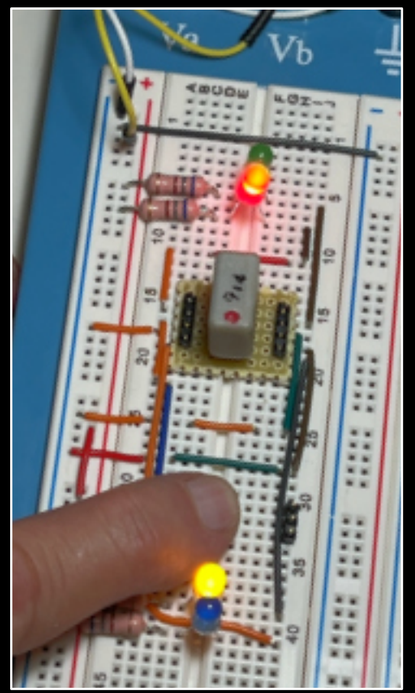
Relays reparation

We introduced the Tektronix relays theme at the beginning of this book, talking about the new solutions of the 7000-Series, describing their benefits and advantages, together with some doubts that we all today have about these old-fashioned components.

Repairing this old stuff, you can discover that, when relays are present, it is likely that possible malfunctions are due to them; but if you think that, after more than forty years, most of them are still in order, we can consider that the Tektronix choice was not so bad. As we noted, Tektronix relays are furthermore very well designed: small, fast and reliable. Most of them, thanks to a very intelligent pin assignment, can also be reversed, i.e. inserted at 0 or 180°.

But how can we manage them today, considering that it is rather difficult to find spare parts? On TekWiki (search "miniature relays") you can find many articles about their reparation/substitution. I can give here some suggestions, based on my experience.

- *Build a relay tester like that in the photo. It is very easy and allows you to quickly understand if a relay is good or less;*
- *The relay tester works not only as a tester but also as an... healing device. I had two cases where a faulty relay started to work after having exercised it on the tester. This medicine is better if you connect the tester to a signal generator and allow it to run at about 7-8 Hz for a couple of hours. Sometime it happens that a relay works well with the LEDs, but not with the weak signal currents. Often, with this treatment, it can be recovered.*
- *It is possible (but not easy) to build a new relay capable to fit in the existing sockets, when you have room enough.*
- *Sometimes, you can transplant a relay of a less important function to other purposes. For example, with 7A13, you can use the S480/490 relays, used for bandwidth limit, to replace S47, 48, 6, 26, 7 or 27.*



Repairing switches and push buttons

Cam rotary switches and push buttons problems due to false contacts of are perhaps the most common (and they were also so, when the equipment was new and young).

In most cases, the problems are due to dirt. Fixing them is not always simple, especially when the contacts are not easily accessible. You can try to flood them blindly with Isopropyl and then dry with low pressure compressed air, but, according to my experience, that is not the best approach; you should look and check the contacts to clean them correctly. Note that sometimes accessing the contacts is easier than you can imagine. For example, initially I did not understand that the attenuator blocks in 7A18, 7A26 etc. could be easily removed, just pulling them.

When possible, the best is a complete wash using a strong de-greaser (I use Chanteclair) and plenty of clean water (better if distilled), but this approach requires drying the board in an oven or at the summer Italian sun. However, I had good results also using a product like WD40 Contacts (not the standard WD40!), helping the dirt removal with a small, very soft brush.

In the most difficult cases, it can be a good idea to well analyze the problem and identify the precise contact causing the malfunction, before trying a generalized washing. In other words, use your brain to identify the wrong contact and operate on that. In the case of 7A18/7A26 attenuators, you can set the knob to 5mV/div (i.e., no attenuation) and place the VOM, in "beep mode", between the in and the out of the attenuator. The VOM should beep. Then move imperceptibly the knob. If the beep ceases, try to find the critical switch with a toothpick.

Normally, push buttons as well can be cleaned with plenty of WD40C (again, not WD40!) , operating them repeatedly.

For other tips, see also the Tektronix "Cam switch repair manual", that you can find rather easily online.

In the photo: a less common problem (I suppose): the hub of the cam cylinder in a 7B53 has come unglued. I doubted I could save it, and fixing was not easy. The problem was to glue the cylinder in the exact position respect to the hub. By comparing with a good 7B53, I could succeed, but two attempts have been necessary.

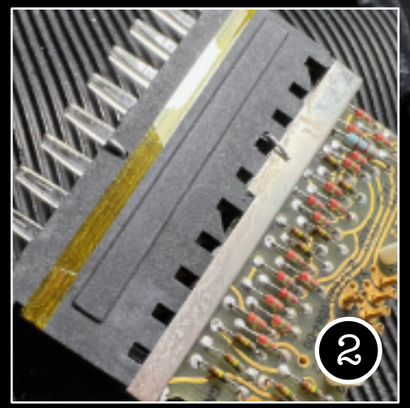
Type 1 (enlightened) pushbuttons

If I am not wrong, the first pushbutton type was that here reproduced, that I call "pin type", constituted by a small transparent plastic stick. They had a nice feature: when you press them, the tip gets illuminated (see next page to see the effect), and that is done with just one lamp for a row of buttons. After a lot of years, these buttons may become critical, especially for the dirt which enters the gear, so they need to be dismounted and cleaned. First suggestion: don't open them unless absolutely needed. This not for their complexity, that requires much of attention and patience, but because they are not designed to be serviced. So, once you have repaired them, there is not a defined way to close them again; the cover is kept in place by small plastic point that cannot be restored when broken. I made some micro-holes and used the rheophore cut off a resistor as closing pin.

❶ The small white shapes have the purpose to make impossible to press two buttons together. They are responsible of the keys hardening. After having well cleaned them and their seat, apply a micro amount of proper grease or vaseline.

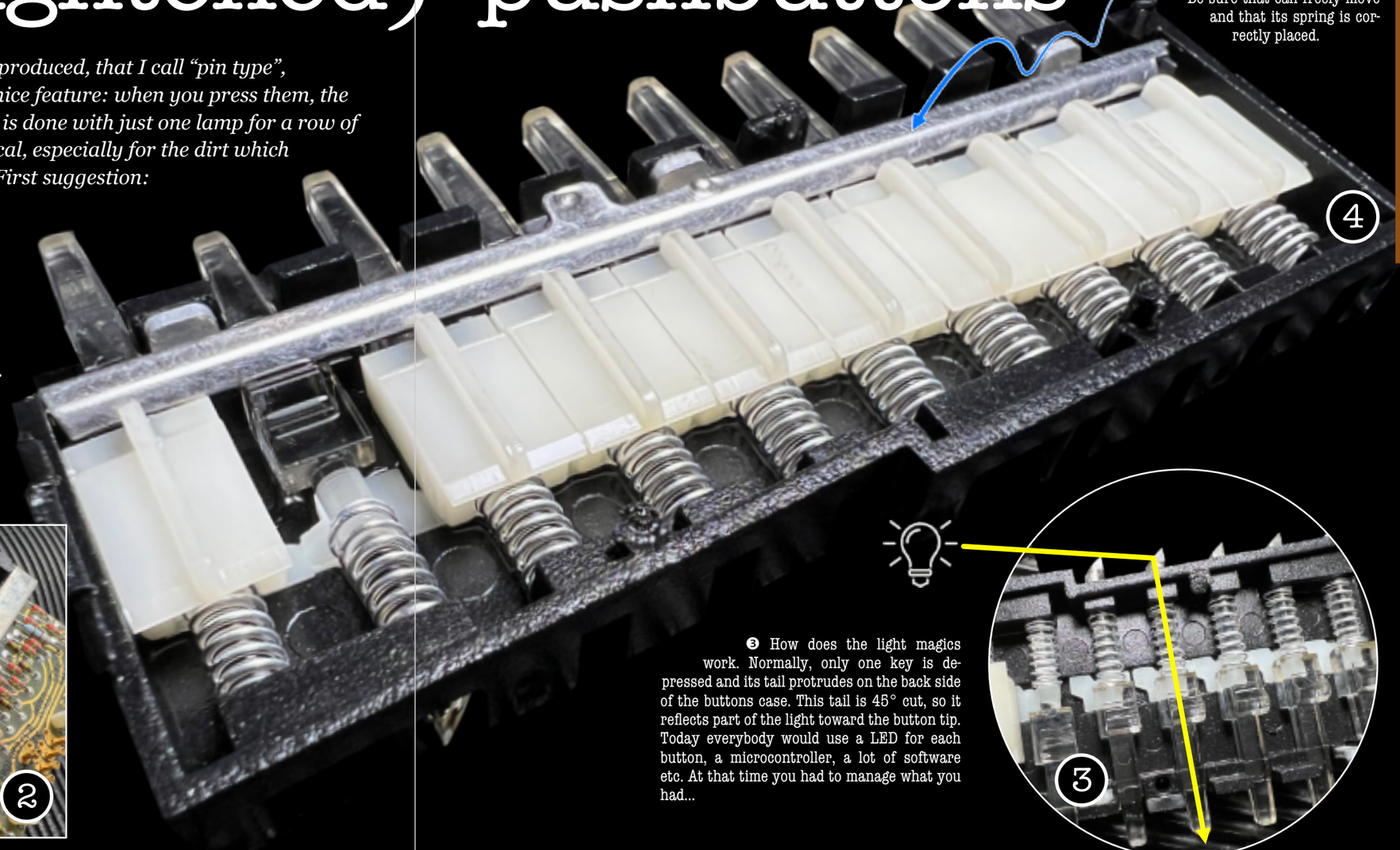
❷ The reworked pushbuttons assembly. Note the new closing pins and the tape to help closing.

1



2

❹ This bar is responsible of keeping the button depressed and to release it when another key is pressed. Be sure that can freely move and that its spring is correctly placed.



4

❸ How does the light magics work. Normally, only one key is depressed and its tail protrudes on the back side of the buttons case. This tail is 45° cut, so it reflects part of the light toward the button tip. Today everybody would use a LED for each button, a microcontroller, a lot of software etc. At that time you had to manage what you had...

3

The Christmas tree

As we told before, the typical Tektronix transparent pushbuttons are enlightened with a very ingenious system that uses just one or two bulbs per row. Thanks to their geometry, only the pressed one conduces the light to its tip. The resulting "Christmas tree" effect is very nice and the enlightened tips makes it easier to understand which button is depressed.

Note that not all the plug-ins are enlightened, even if they have these pushbuttons. The most glaring case is the 7B53A, so don't worry if only the single sweep button has the light, it is not a fault but a designer's decision.

Neither do the three-bays mainframes like 7603 and similar, which have not the necessary power supply for the lights; but they can be easily modified as explained on next page.

Lamps

At first I believed that replacing a lamp could be very easy, but nothing is free, and Tektronix did not make things easy. There are many kind of lamps, and they are not everywhere available (i.e. in Europe); on eBay they are furthermore often unreasonably expensive.

A good place to buy them is Bulbs.com, 234 Stafford Street, Worcester. MA 01603 (customerservice@bulbs.com), but, if you too live in Europe, you will have to pay the shipment, wait and wait, and pay the custom.

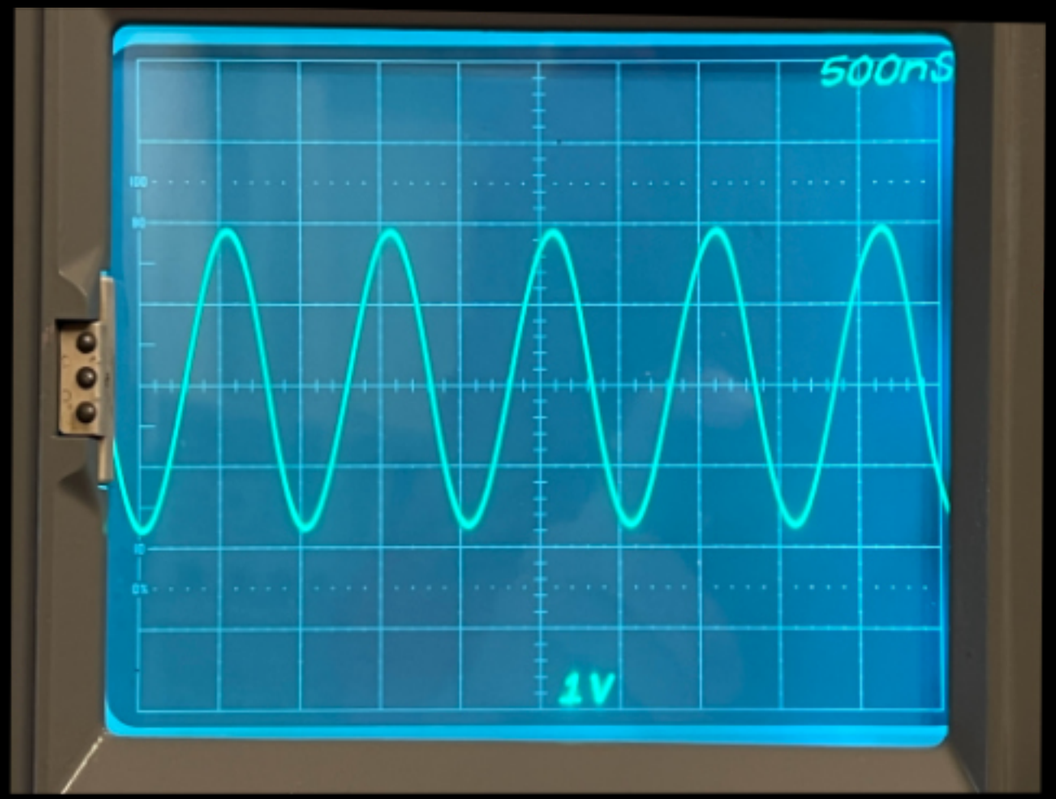
There are millions of lamp types, in millions of variants. Most of them are identified by an ancient code, but often not unique.

Until now, I came across three lamp types:

- *150-0047-00, aka "#398", 6.3V, 0.2A, dia 5.9mm - it is used for the graticule illumination of the 7603 and other with the same size CRT (es. OS-245(P)/U). They are removed pulling from the front (be careful, they break easily);*
- *150-0029-00, aka "#349", aka "7381", 6.3V, 0.2A, dia 6.2mm - it is used for the graticule illumination of the 7904 and other with the same size CRT (es. 7844, 7623, 7633...). They are removed from the rear, moving slightly a clip. I bought them from Bulb.com;*
- *150-0048-00, aka "#683", 5V, 0.06A, dia 3mm - it is used for the pushbutton array illumination (that described here some pages before). They are soldered and not easy to change. In many cases, it is necessary to disassemble a lot. I replaced them with the Mouser 606-2 (5V, 0.02A, dia 2.2mm, that are bright enough).*

The genial gear, described in the previous pages, that ensure the illumination of the Tektronix pushbuttons. They are not powered on the 76xx oscilloscopes. The plastic part subject of the photo belongs to a 7B70 plug-in, that had all the bulbs burned out. I has obvious signs of molding. Perhaps it received an over-voltage, that caused overheating and filament destruction.

LED light modification

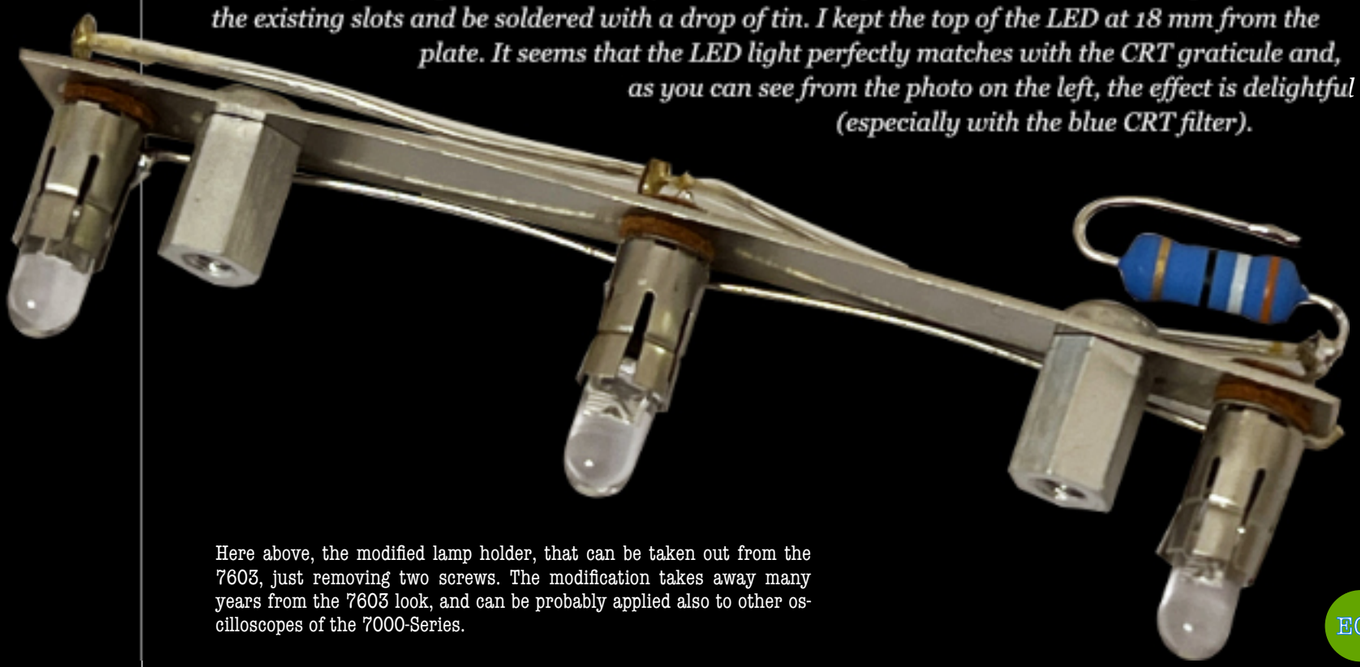


Here I suggest you a little facelifting for our old friends: replacing the lamps with modern LEDs. I am normally a maniac of absolute originality, but the effect of this modification is so nice that I made an exception.

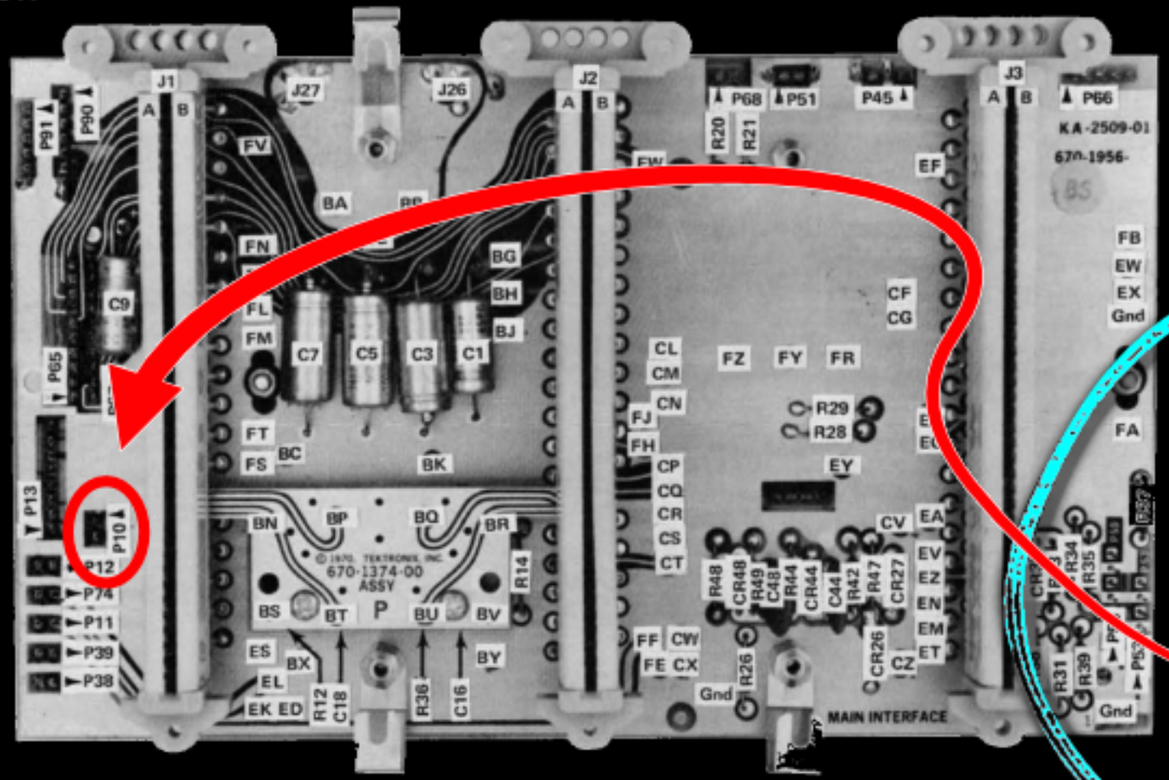
The idea is not from me but from a Youtube video by Zenwizard Studios (https://www.youtube.com/watch?v=xNx9IgudV4Y). I just add some bits of information.

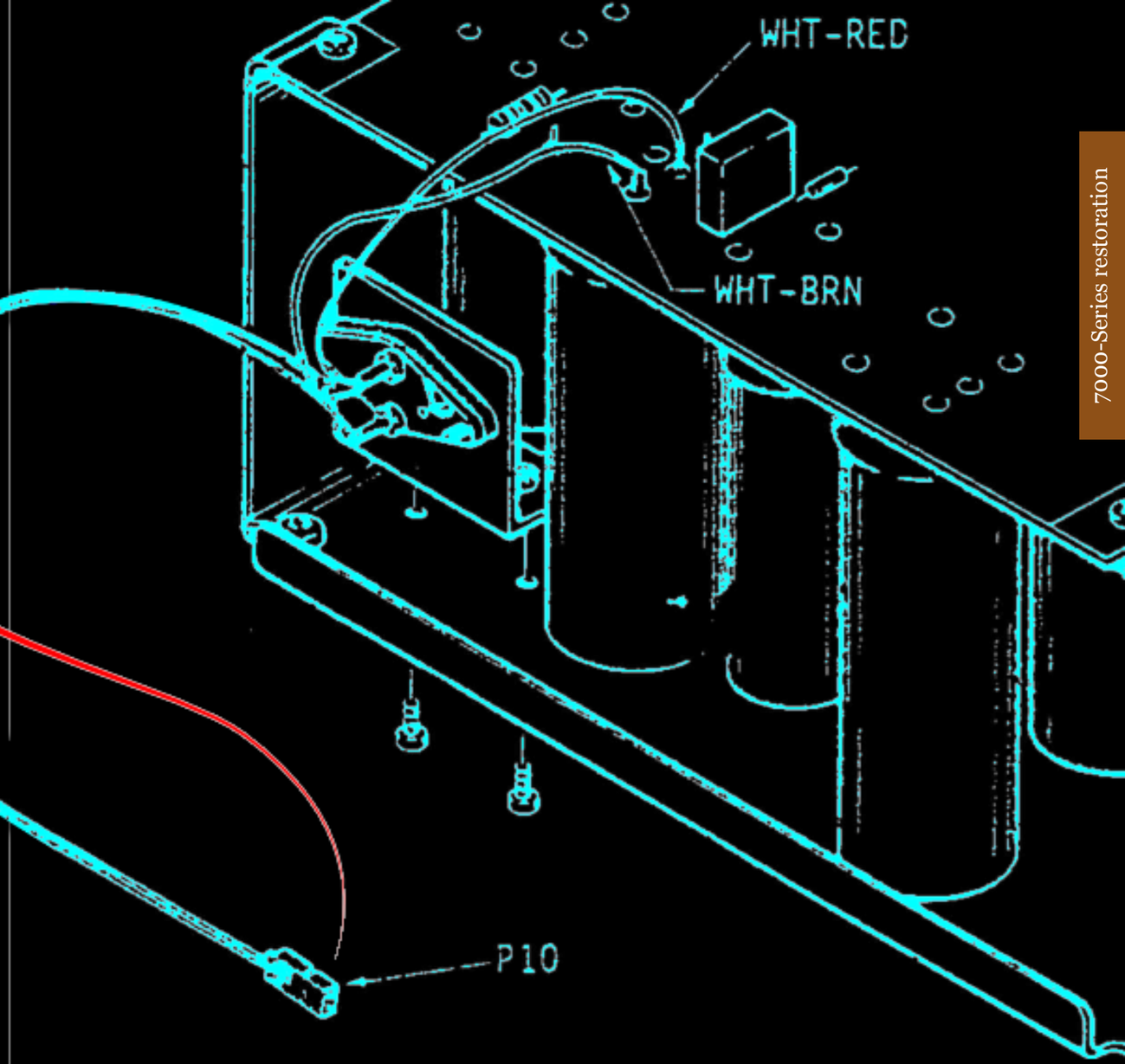
I used high-efficiency 5 mm white LEDs that I bought on Internet. Today LEDs are absolutely fantastic. These are rated for 50 mA, but they seem to go much further, even if probably with a shorter life. In theory, you should add a resistor for each of them. The author of the idea used no resistors at all, but I found prudent to add at least a 39 Ohm, ½ W resistor in series to them all, also because it is useless to use too much light.

Mechanically, I used a drill with 1 mm tip to remove the internal original spring and used the existing hole for the positive terminal of the LED (the longer one). The other lead can pass between the existing slots and be soldered with a drop of tin. I kept the top of the LED at 18 mm from the plate. It seems that the LED light perfectly matches with the CRT graticule and, as you can see from the photo on the left, the effect is delightful (especially with the blue CRT filter).



Here above, the modified lamp holder, that can be taken out from the 7603, just removing two screws. The modification takes away many years from the 7603 look, and can be probably applied also to other oscilloscopes of the 7000-Series.





Gimme the light!

The four bay oscilloscopes, such as 7704 or 7904, provide the +5V for the button lightning, and so the beautiful effect previously shown. But the 7603 and similar scopes (7613, 7623, 7633 etc.) were perhaps the sons of a cost reduction process, so that supply was removed. To add it back is however easy: you need only a 3-terminal regulator (e.g. the 7805) and a metal bracket, as shown in this photo, with a cable porting this +5V supply to the P10 connector on the interface board.

Note anyhow that also the plug-ins that were designed mainly for this equipment have no lights: the 7A18 and 7A26 simply have no pushbuttons to enlighten. The 7B53A has the pushbuttons but... not the lamps inside. So, the work is convenient only if you have other plug-ins.

The readout and a challenge

This evening I am curious about the 7000-Series readout system and I try to investigate the dialog between a 7A26 and a 7603 mainframe. I should like to display something on the CRT from an Arduino board, in the future.

Simple for the plug-in. *Even if it seems weird, I must admit that the 7000-readout system is really very, very simple from the point of view of the plug-ins. If the text to display is almost static, only few resistors are required on the plug-in side, obviously together with the switch and perhaps few diodes.*

To each his own. *There are eight fixed positions (six in three bay-scopes) for text on the screen, each is ten characters long. In correspondence with the bay, each plug-in has two position available, one in the top part of the screen and one on the bottom part.*

Questioning. *There are 10 pins on the plug-in connector (T1…T10). T1 pin receives from the mainframe a -15V pulse that asks the plug-in "which character do you want to display in position 1?". Then is the turn of T2: "which character do you want to display in position 2?" etc. Every Tn pin asks for a character by sending its negative pulse, in sequence from T1 to T10.*

Answering. *How can the plug-in answer these questions? In a very peculiar way, really. The plug-in has available four pins to reply, a pair to write in the top position, and a pair for the bottom position (eg. CH1 on top, CH2 on bottom). Let's talk only about CH1, CH2 is identical. The plug-in channel 1 must connect each interrogating pin with these two pins by mean of two resistors, thus producing in sequence a pair of currents for each T1, T2…Tn.*

Current encoding. *Each current value stays for a number from 0 to 10, according the current encoding table here on the right. Each pair is interpreted as (x,y) coordinates (row and column) for the Character Selection Matrix that contains the displayable characters (see next page). For example, row=1 and column=2 identify the character "1".*

CURRENT ENCODING TABLE			
I (mA)	R	If row	If col.
0	∞	1	0
0.1	150k	2	1
0.2	75k	3	2
0.3	50k	4	3
0.4	37.5k	5	4
0.5	30k	6	5
0.6	25k	7	6
0.7	21.5k	8	7
0.8	18.75k	9	8
0.9	16.6k	10	9
>1	13k	NA	10

Most of the ICs on the mainframe readout board are Tektronix custom.

ROW NUMBER \ COLUMN NUMBER	CURRENT (MILLI-AMPERES)	C-0	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
R-1	0	SKIP'	0	1	2	3	4	5	6	7	8	9
R-2	0.1		!	<	I	/	+	–	*	C	Δ	>
R-3	0.2		ADD' ONE ZERO	ADD' TWO ZEROS	SHIFT' PREFIX ←	SHIFT' PREFIX ← AND ADD ONE ZERO						IDENTIFY'
R-4	0.3		m	μ	n	p	X	K	M	G	T	R
R-5	0.4		S	V	A	W	H	d	B	c	Ω	E
R-6	0.5		U	N	L	Z	Y	P	F	J	Q	D
R-7	0.6				DECIMAL' POINT LOCATION NO. 3	DECIMAL' POINT LOCATION NO. 4	DECIMAL' POINT LOCATION NO. 5	DECIMAL' POINT LOCATION NO. 6	DECIMAL' POINT LOCATION NO. 7			
R-8	0.7										DECIMAL' POINT	
R-9	0.8											
R-10	0.9	ADD SPACE IN DISPLAY'										

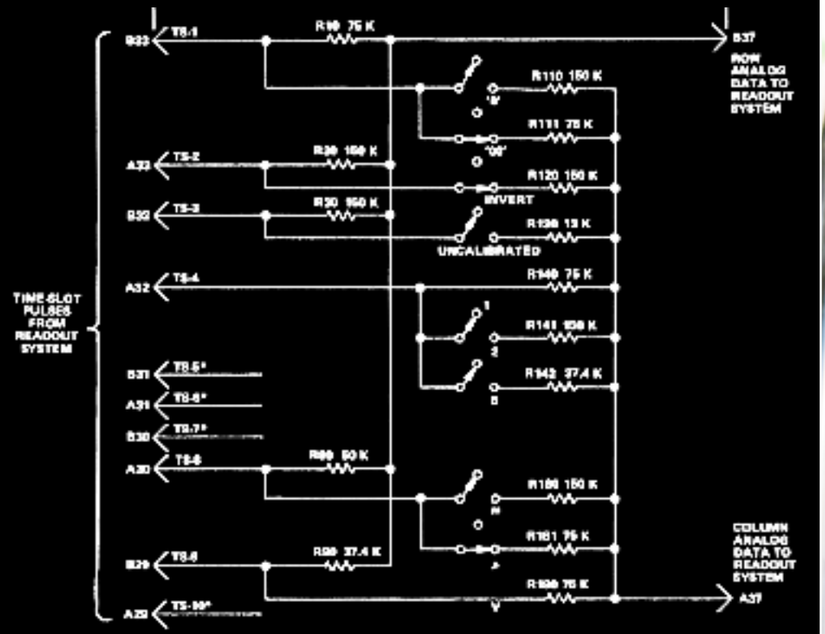
Special characters. *Some positions in the matrix have special meaning to make more efficient the dialog; for example, row=3, column=2 in the first position is a command that says "add two zeroes to the following number". Note also the SKIP command: if the plug-in has no resistor on the zero column, its current is null and the state is skipped, producing the shortening of the cycle from 250 to 210μs, but, above all ,avoiding to interrupt the signal trace for the readout.*

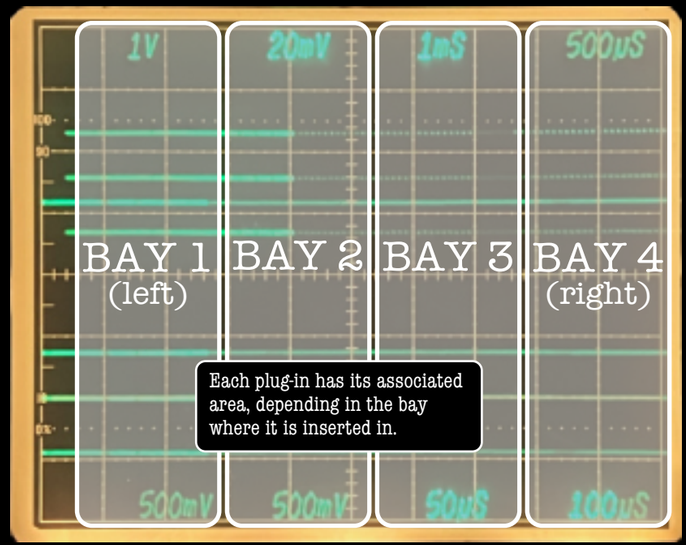
What will appear? *A more complex example from TekWiki, that was not so easy for me at the beginning. I hope that the extra information here reported can be useful for somebody else. Look at the circuit on the next page: it could be a vertical amplifier plug-in. Let's try to guess what string will appear on the screen. With all the information we gave here, it's rather easy: the string is "↓100μV", as shown by the table here on the right.*

Read the TekWiki page or the manual of a mainframe to know more.

TS	R	C	Meaning
TS-1	3	2	Add two zeroes
TS-2	2	1	"-"
TS-3	2	10	'>'
TS-4	1	2	'1'
TS-5			Not used
TS-6			Not used
TS-7			Not used
TS-8	4	2	'μ'
TS-9	5	2	'V'
TS-10			Not used

Probes: as many know, the 7000-Series readout system is capable to identify the x10 probes and correct the display information. For example, if you set the knob on .5V/div, the readout should indicate 5V/div, when you use a x10 probe. That is done by inserting a fixed resistor between the ring that surrounds the BNC input connector. Its value is less known: it must be 10 or 11kOhm.

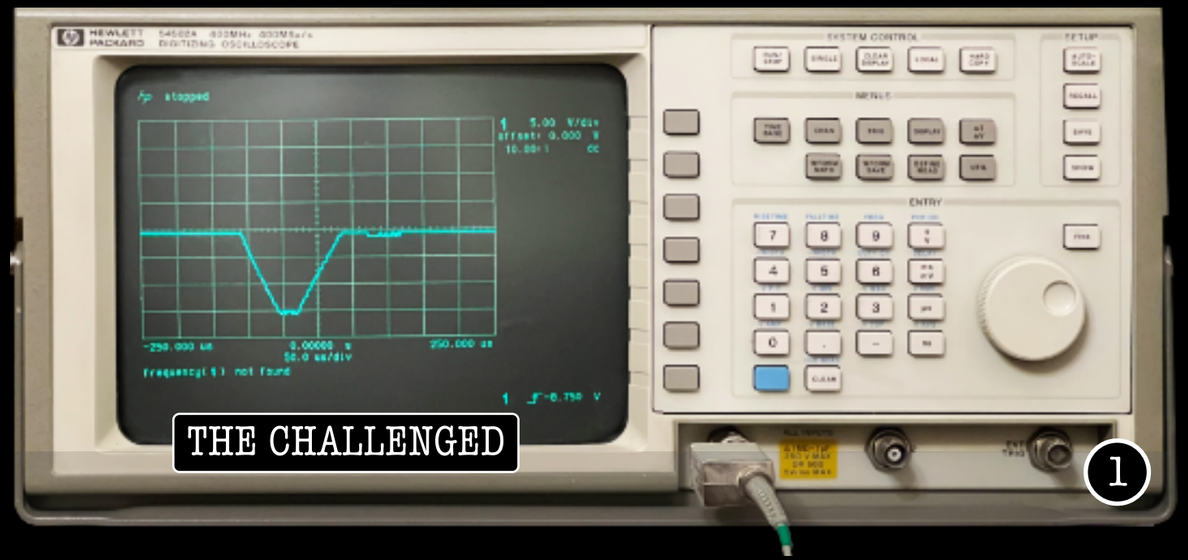




The challenge

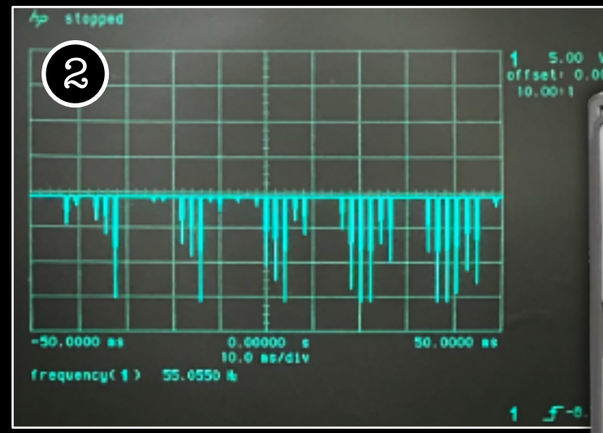
So, back to the beginning. This evening I am going to look at the T question pulse, to see if the practice coincides with the theory. I get the T4 signal on pin A32 of a 7A26 plug-in in a 7603 mainframe (@200us/div) and I try to examine it with my HP 54502A digital storage oscilloscope, not very new indeed (1991) but, with its 400MSa/s, is a spaceship, compared to my old stuff from the '70.

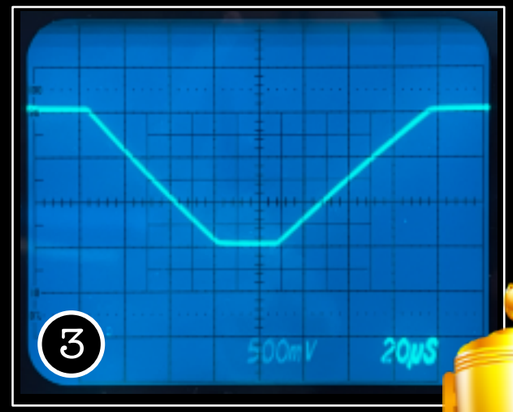
I can get very easily observing the T pulse (photo 1). The digital storage is a great thing! Things become worse when I try to observe the pulse train, and all I can get is shown in photo 2. You can imagine that the temptation was strong... and what if I tried with the old 7633 CRT storage scope? In few minutes I am ready for the match. I start trying the non-storage approach with the 7633. The result is not bad, but the repetition rate is low and I am non able to take a decent picture (the iPhone has perhaps its timing requirements, so I lose part of the trace). OK, I tell to myself, lets try going storage. This requires some attempts to get the optimal setup. The best results are obtained in single shot, VAR PERSIST, keeping the intensity not too high. The result is in photo 3, not bad at all. In Italy we have a proverb that says "the appetite comes with eating", so I want to dare more, and try a mixed display using the delaying time base. Very good (photo 4)! But the real difference is obtained with the pulse train, that is captured much, much better than with the more modern DSO.

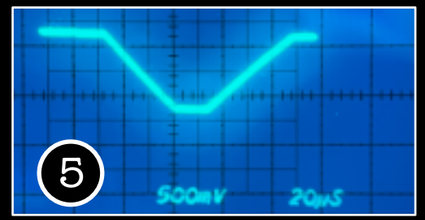


The crowd breaks out into shouts of enthusiasm, and the 7633 is bursting with pride!

To complete the picture, I took a photo also in the reduced scan mode. The writing speed was not a problem even without the FAST, so there is not a big difference (photo 5).







465-Series oscilloscopes

OK, a little off-topic, but I like them also...

The 465 can travel with you

This is not 7000-Series, but I like it so much and I don't want to ignore it. The Tektronix 465 is a portable 100 MHz dual-trace oscilloscope with dual time-bases, introduced in November 1972, based on the same technology as 7000-Series. It is all solid-state except for the CRT. The 465 was very popular and Tek made them for quite a few years. According TekWiki, microfiche records tell about 37 variations of the 465.

I consider it something like a portable version of the 7603, with 7B53A and 7A26 plug-ins (without readout, but with a smart backlighted V/div knob, a poor man substitute for the readout…).

The delaying time base uses a knob similar to 7B53 7000-Series plug-in, but with a slightly different logic: instead of a not-always-intuitive pull & push, the 465 allows to explicitly request what you want to see, by mean of four dedicated buttons.

Still today, the 465 is very practical and pleasant to use. No surprise that it was so successfully when introduced. You can still find 465/475s on eBay for 40-50€.

My 465, after all these years, is still well calibrated and outperforms the declared bandwidth by more than 30%.

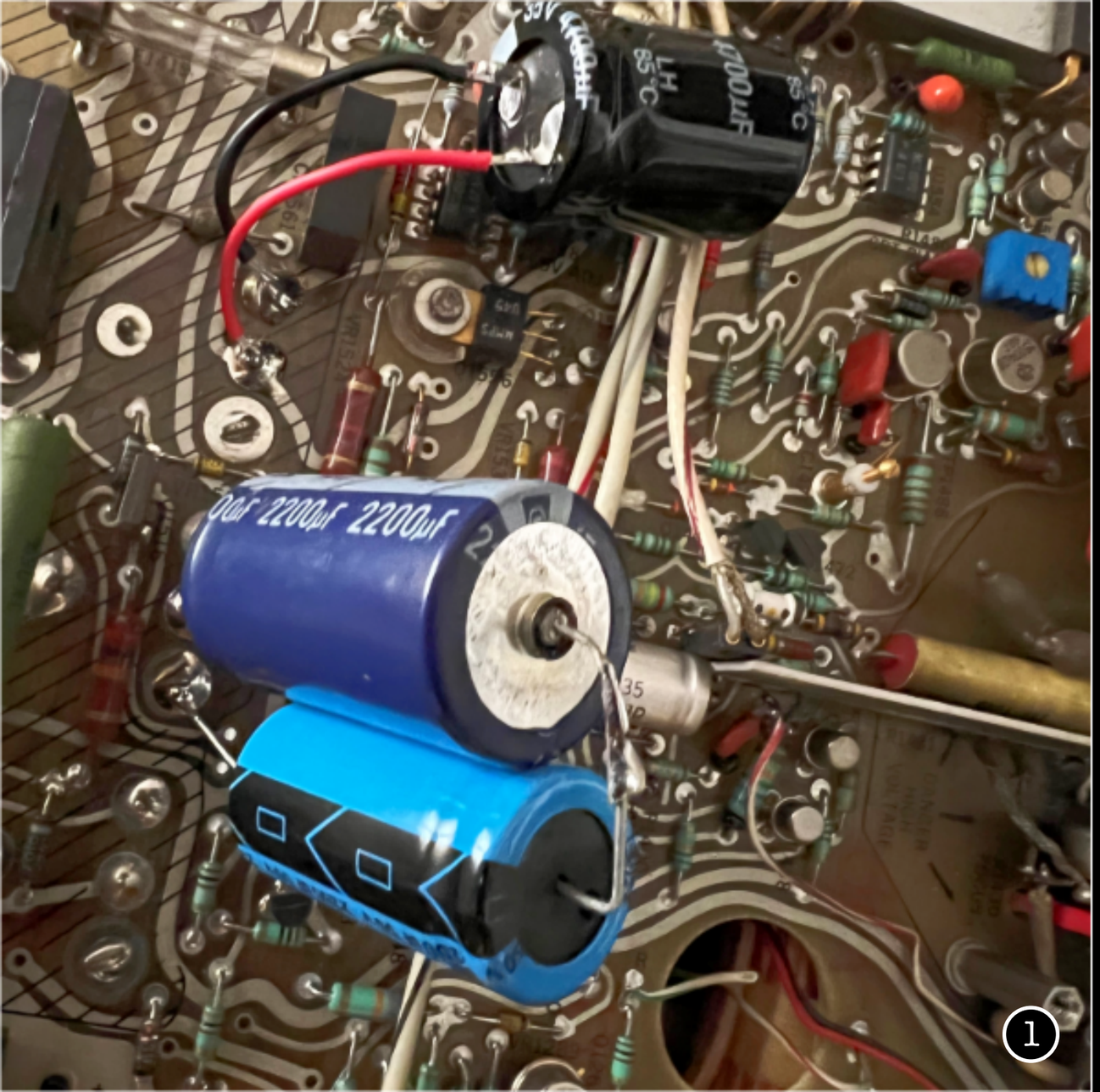
1972

Recapping the 465

The 465, as the similar members of the family, are very well engineered and use at best the available volumes; that is positive but makes it more difficult to work on them.

My 465 arrived to its new home as "spares only". As I hoped, it had only the power supply filter capacitors defective. You can easily check them and add some external capacitors as shown in photo ❶ (old ones normally don't explode, they just become open) to see it alive. Replacing them is however not very easy and, to avoid damaging the PCB, require some dismantling. To remove them I use an electric saw and some hard work (photo ❸).

When you install the new capacitors, be sure to restore the connection that were made by the capacitor body itself (wires enhanced in red in photo ❷).



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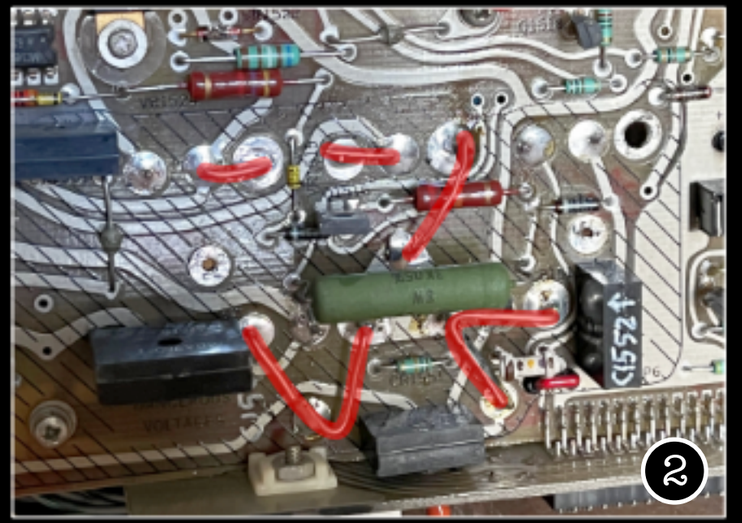
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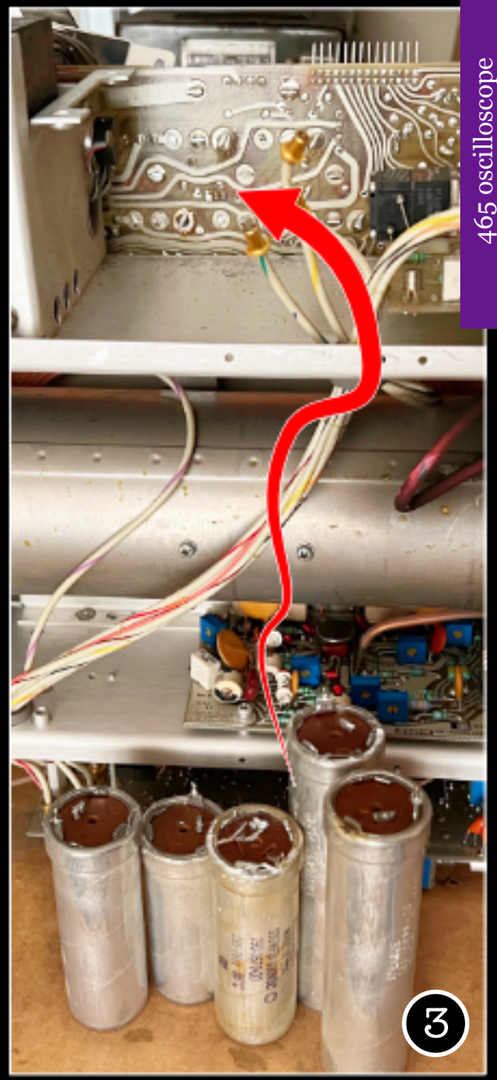

3

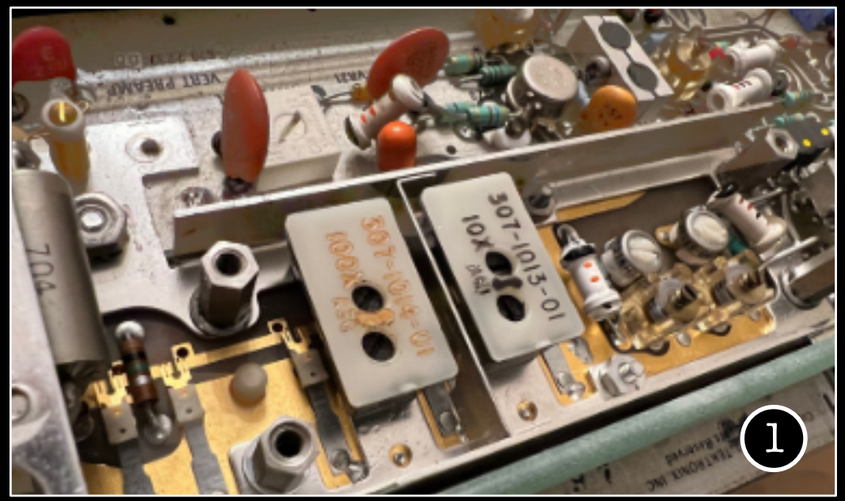
The 465 attenuator

Often the vertical input attenuator is the first part that gives problem, especially for the noisy switche So, understanding how it works is convenient to remedy the defects. The 465 uses two real attenuators (X10 and X100) and an amplification reduction with three levels (X1, reduced X2, reduced x4). Like many other Tektronix devices of that time, the real attenuators are made by unrepairable, pre-built modules (photo ❶). They can be easily removed, simply pulling them out; doing so, you can comfortably get access to the underlying gold plated contacts, where normally the devil lurks... (photo ❷).

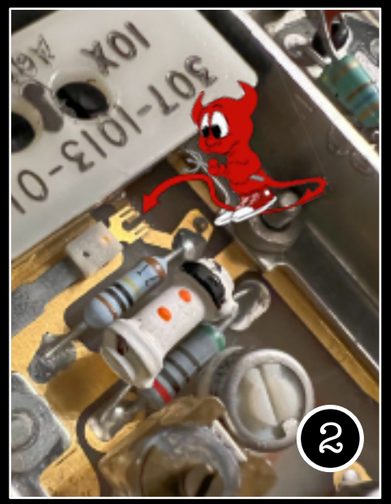
In most cases, WD40 Contact (not normal WD40!) and a soft, small brush are enough for cleaning. In few cases, you will need and ultra-fine sandpaper and a very delicate hand to restore them into operation.

As indicated in other part, my 465 presents an impressing 135 MHz bandwidth, still exceeding the nominal value (100 MHz).

	Attenuators		Amplifier	
	X100	X10	X4	X2
5mV				
10mV				X
20mV			X	
50mV		X		
0.1V		X		X
0.2V		X	X	
0.5V	X			
1V	X			X
2V	X		X	
5V	X	X		



❶



❷

1972

Something else

I could not find another place to put this stuff.

Revision history

Rel.	Date	Notes
1.0	*September, 15, 2022*	*First edition (2022) independent from the Photo Parade book. A lot of things added and revised.*
2.0	*October 15, 2022*	*The instruction for the vertical amplifiers calibration have been moved to the "Restoring Tek scopes" section. Pages added to explain the 7A13 attenuation circuits. Pages added about relays restoration. Revised the page on Tek relay. In consequence, the notes on potentiometers have been moved to dedicated pages. Added pages on Tek switches restoration. Added pages on prices in the time analysis. Added pages on 7A12, 7B80, 7B85. Added four pages on the readout system. Added pages about the challenge of 7633 with HP545902A. Added pages about 76x3 key enlightenment. Page added on plug-in front panels. Pages added on 465 oscilloscope. Pages added on bandwidth & rise time. Pages added on illuminated push buttons. Pages added on CRT display information content. Pages added on models comparison. Added a section on 7603 wiring. Added pages on 7603 base model. Added pages about distributed plates. Added pages about 7844. Added pages about oscilloscope photo cameras. Pages added on negative options. Many corrections.*
3.0		*7603 big drawing added with boards location. Added pages on fan and 440Hz. Page added on plastics. 7844 rewritten, with more photos. Photos added on 7904. 7854 added. Section added on VintageTEK museum. Added pages on Digital Equipment PDP-8. Added pages with the photo-list of mainframes. 7A24 added. Pages added about prices. Revised page on 7833 and added pages with 7834 and 7934. Added pages on ripple measurement.Pages added on lamps. Notes added on 7A22 fuses. Added pages on the amplifiers comparison among models.*

About me

About me

My name is Giovanni Becattini (but everybody calls me Gianni) and live in Florence, Italy. I started loving electronics when still a boy, and I have been working in professional electronics for more than 50 years, spending my entire life in electronic industry.

All the photos here have been taken with a normal iPhone 13 Pro and edited with Affinity Photo. This document has been created with Affinity Publisher.

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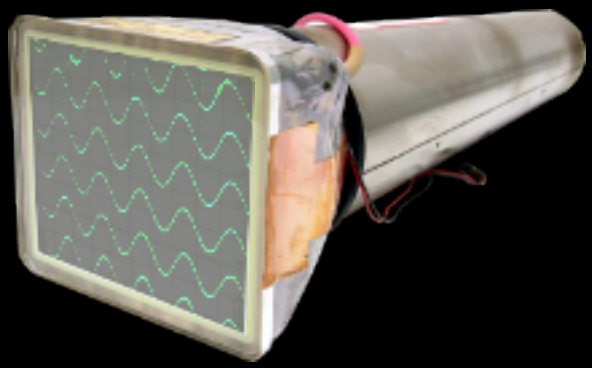

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